FOOTSTEPS IN CIVILIZATION

By the same author

THE ROMANCE OF GARDENING
PLANT HUNTER'S PARADISE
MODERN EXPLORATION
ABOUT THIS EARTH
ASSAM ADVENTURE
COMMONSENSE ROCK GARDENING
BURMA'S ICY MOUNTAINS
PLANT HUNTER IN MANIPUR

FOOTSTEPS IN CIVILIZATION

by

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(Gold medallist, Royal Geographical Society, Royal Scottish Geographical Society, Massachusetts Horticultural Society, Royal Horticultural Society)

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THE SCIENTIFIC BOOK CLUB
121 CHARING CROSS ROAD
LONDON W.C.2

PRINTED IN GREAT BRITAIN IN THE CITY OF OXFORD
AT THE ALDEN PRESS

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THE AGES

Geological Horizon	*Culture*	*Began in Europe (about) B.C.*
	METAL AGE	
Recent and Post-Glacial or Modern Interglacial	Iron	750
Quarternary Age begins	Copper and Bronze	1000
	STONE AGE	
Pleistocene Age ends, and with it, the Great Ice Age	Neolithic	2000-5000
?5000 B.C.	Mesolithic	10,000-5000
4th Glacial (Würm)	Palaeolithic	20,000
	PREPALAEOLITHIC	
3rd Interglacial		75,000
3rd Glacial (Riss)	Eoliths	100,000
2nd Interglacial		350,000
2nd Glacial (Mindel)		500,000
1st Interglacial		600,000
1st Glacial (Guntz)		
Great Ice Age begins		750,000
Pleistocene begins		1,000,000
Pliocene ends		

Compiled from various sources, including Reid Mois, Scott Elliott Wells,

OF MAN

Primates known to exist	*Remarks*
HOMO Modern Man (*Homo sapiens*)	All the great discoveries and inventions discussed in this book, with the exception of fire, fall well within the last 20,000 years and probably within the last 10,000. That is to say they were made between 8000 B.C. and the present day.
Cromagnon Man and other cave dwellers (*Homo sapiens*)	Man is very much older than the earliest of his discoveries. Apart from the discovery of new raw materials and atomic energy, man's last invention was the power engine. The ice may have finally disappeared from the European plain, leaving the coastline more or less as it is today, about 7000 B.C.
Homo neanderthalensis (*Homo non-sapiens*)	About this time the glaciers of the 4th and last glaciation began to retreat and *Homo sapiens* may have appeared on the scene about this time, say 25,000 years ago. He may have had fire under control.
NON-HOMO Piltdown Man	Ape-men or sub-men from several parts of the old world, including *Pithecanthropus erectus*, Java ape-man.
Heidelberg Man Galley Hill Man and others	Some of the later sub-men, who lived 500,000 – 1,000,000 years ago, are believed to have possessed fire, e.g. *Sinanthropus*. It is less certain that they could make it.
The men of South Africa, of Peking and of other places	Eoliths may have been made by any of the known genera of ape-men, or by some as yet unknown type.
Unknown ancestors of Man with no anthropoid characters	

le Gros Clark, Graham Clark, Zeuner, and others, and slightly modified

ACKNOWLEDGMENT

THE *illustration of the warrior of Ifitamin is based on a* photograph by Major Simmons S. Smith; the Arnhem nomad making fire with fire-sticks on a photograph by Donald F. Thomson; the South-Sea Islander eating a raw fish on a photograph by the Australian Research Council; the fuzzy-haired Hadendoa on a photograph by James C. Wilson; and the maize-husking mill on a photograph by Ernest B. Schoedsack.

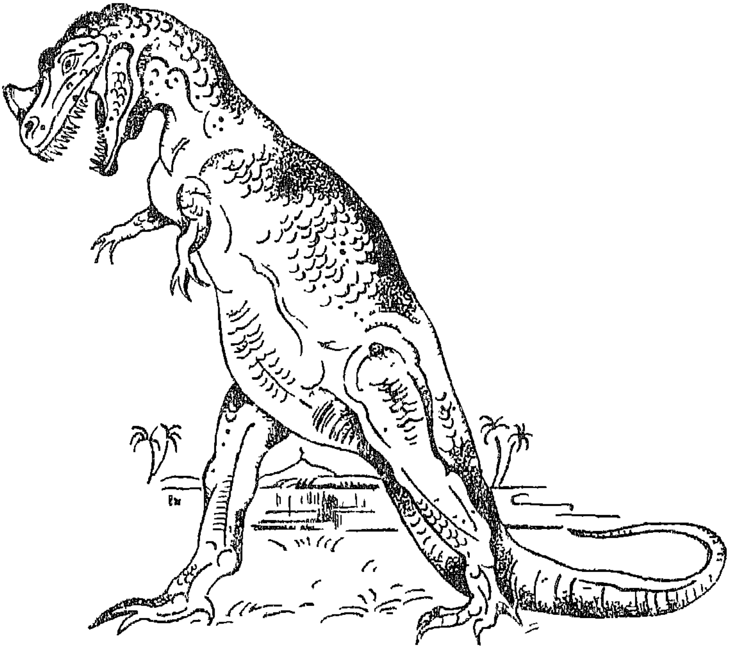
FOOTSTEPS IN CIVILIZATION

CHAPTER I

THE FILM OF LIFE

BEFORE discussing the steps by which Man has raised himself to the top of the tree of life, it will be useful to say a few words about life in general as we know it on this Earth.

It is quite possible that the origin of life is the last unfathomable mystery; that we shall solve every other problem and still be left with the one problem of all problems on our hands, unsolved and insoluble. Be that as it may, if we think of the life all around us, we are likely to be struck by two facts which would be regarded as curious, were they less familiar. First, that life, as compared with the great bulk of the Earth over which it is spread, is exiguous – a mere film of living matter, less than the scum on a pond. This is not generally realized, perhaps, because we rarely contemplate such aspects of life. Secondly, that every unit of life, plant or animal, however large it may be or however old, began life as a single cell invisible to the naked eye. This is as true of the giant tortoise of the Galapagos Islands, waddling across the wind-swept rocks inside its grim centuries-old tank; of the great bull elephant charging through the African forest while it trumpets defiance; of the huge Greenland whale (largest of living animals), as it is of the duckweed floating on a pond, and of the big trees of California which rise 300 feet into the sky and were old when Caesar conquered Gaul. It is as true of the most exquisite humming bird; of the gorgeous swallowtail butterfly, rocketing across the tropical glade with a flash of iridescent blue, as of the ugliest fish from the everlasting night of the ocean abyss – a creature that is nearly all mouth and always hungry. And mark well that it is true also of those huge beasts of which we read (whose skulls and bones we find in the clay beds and chalk), which cluttered the Earth many millions of years ago, the long extinct giant lizards, as stupid as they were ferocious.



Ceratosaurus (horned lizard), a carnivorous dinosaur About 20 feet long

Every animal and plant that lives, or ever has lived, began life in the same way, as a single tiny cell. In the unicellular forms of life, the single cell which *is* the organism – plant or animal – divides into two and the two cells separate, thus increasing (or reproducing) the species. Here life begins – and ends – as a single cell. In a sense, however, its life never does end, unless it is swallowed up by something larger than itself, a whale, for instance (many whales live largely on almost invisible unicellular organisms); it just goes on dividing into two, and the two halves divide again, and so on for ever. It is immortal. Each unicellular organism is, in fact, part of a single clone, a clone which has existed for millions of years.

In all but the simplest forms of life, however, this single starting cell, plant or animal, is the female egg cell, although unless it is first fused with a single male cell (sperm) it has no power of growth or further development. Presently it dies. But when fused with a male cell, which is completely merged in it so that the twain are physically one, our single cell grows and multiplies in exactly the same way (to begin with) that a unicellular organism grows and multiplies. Immediately, however, two marked differences appear.

In the first place, the primary divisions do not result in two distinct organisms – they do not separate; on the contrary they remain firmly held together. There is fission without separation. And the cells continue to divide and grow, grow and divide, building up an ever larger structure, a multicellular organism. Secondly, *differentiation* sets in. The cells, at first all alike, begin to form themselves into recognizable groups, and the differences between one group and another increase. The outline of the varied tissues which make up a complex organism can presently be distinguished.

Now, Life is only life within comparatively narrow physical limits which, taking the Earth as a whole, are quite exceptional. The Earth itself is a speck of rock in the immensity of the universe, and there is good reason to believe that life as we understand it occurs nowhere else but on this speck. Thus life is a rare phenomenon, not only in the universe, but even on the one tiny planet where it is found at all. Life exists as a mere film because the conditions under which it is able to sustain itself occur only within a film, varying in thickness, but nowhere more than a few miles thick. That may sound a lot; but consider it carefully.

The Earth comprises a series of hollow spheres wrapped round each other (or one inside the other), and of different depths or thicknesses. Of these, three are familiar to us all and easily recognized. The outermost is the *atmosphere*; inside that is the *hydrosphere*, or water stratum (the sea in ordinary language, but including also land-based water, as rivers and lakes). The sea covers only about three-quarters of the globe owing to the fact that it has been interrupted here and there by the solid innermost shell, or *lithosphere* (known also as the crust of the Earth), which has been pushed up through the yielding hydrosphere in many places to form the continental lands. The innermost wrapping is the Earth's crust, continuous over the entire surface, but for the most part invisible, being covered by the opaque hydrosphere; just as the hydrosphere itself would be invisible if the atmosphere, instead of being transparent, were as thick as cloud or fog. (It often is.)

The crust in turn covers the core of the Earth, which also is solid or, more likely, plastic. The thickness of these three shells is, with the exception of the hydrosphere, difficult to estimate. They cannot be directly measured and have to be inferred. The atmosphere is believed to be some hundreds of miles deep, although at a height of only twenty-five miles or less above the Earth's surface it cannot be detected, even by the most delicate instruments yet made. The sea, as we know, varies greatly in depth, depending on the irregularities of the crust whose hollows it fills; but nowhere does it exceed eight miles. The thickness of the crust is probably the most difficult of all to estimate, but there again we can say confidently that it does not exceed about twenty-five miles, and may be less. Below that, all rock would presumably be plastic and comparatively homogeneous. The core of the Earth is believed to be partly metallic, however, at least towards the centre.

Now, the diameter of the Earth is about 8000 miles or rather less – this includes both hydrosphere and lithosphere, since the atmosphere rests directly on the hydrosphere. If we take the depth of the atmosphere to be 500 miles – a generous estimate – we get a total of 4500 miles for the thickness of the three shells plus the thickness of the central core. It is known that life extends upwards into the atmosphere less than ten miles (in contact with rock, less than five miles) and downwards into the hydrosphere perhaps an equal distance. So far as the lithosphere is concerned, however, life is entirely on the surface, except where there is soil, which it penetrates to a depth of at most a few hundred feet, as in the roots of trees. Caves must be regarded as surface features, since they are connected with the atmosphere.

Thus ten miles appears to be the maximum thickness where conditions which will support *any* life on the Earth occur; and this is the maximum thickness of the film of living matter which has spread itself over the face of the Earth. But in many places it thins out to a mile or less, as, for instance, over the great desert regions. Over the South Polar continent there is probably no life at all, either on the land or in the air, and the film thins out to nothing. Even under the most favourable conditions, where the life-containing zone might be ten miles, it is very thinly spread towards the upper and lower limits. Ten miles is 0.002 of the total thickness of the Earth, which is proportionately much less than the thickness of the skin of the largest apple. It is, of course, because the physical limits within which it is possible for life to exist are so narrow that the film is so thin.

But it is when we come to consider this film of life in comparison with the *volume* of the Earth that we realize how tenuous it really is. The total volume of the atmosphere is of the order of 900,000 million cubic miles; of the sea, 300 million cubic miles, and of the solid Earth, 250,000 million cubic miles. It would seem, then, that life does not take up very much room in the universe, or even on the Earth! If life averaged one mile in depth over the entire surface of the Earth, its volume would be only 4130 million cubic miles, most of which would still be empty of life.

It is difficult to imagine a time when there was *no* life on the Earth. And yet, such a time there must have been. How long ago? It would be rash to guess, though estimates have been made; but unless evolution proceeded much faster in the beginning than it seems to do now, it would require time of the order of 2,000,000,000 years to account for all the changes that have taken place. Just as every separate animal and plant began life as a single cell, comparable with the simplest forms of life which still exist, so also Life as a whole – including Man – is believed to have evolved from simpler and ever simpler forms, stretching back into the dim remote past, further and further, until finally we arrive at a stage when *all* life consisted only of single-celled forms; and aeons before that, to an age when there was as yet no life on the Earth.

At what stage, then, does Man appear on the scene, as the latest of nature's experiments? It is impossible at present to say exactly; but very late in the history of life, though very early (that is to say, a long time ago) as time is ordinarily understood. He comes at the end of the story, so far as it has been told. But the real end is not yet.

All life exists by virtue of its adjustment to a particular environment and to particular conditions which are relatively – but *only* relatively – stable. If the environment changes noticeably, if, that is to say, the conditions change, all the life which was adapted only to that particular environment must change with it, migrate to a suitable environment (if it can find one), or cease to be. Environments change slowly, but they do change. The life itself has an inherent tendency to change; it also is only relatively stable. It is possible, indeed, that many of the changes in the forms of life inhabiting a given area have been brought about owing to the differential rates of change of the environment and of life itself.

As already remarked, all life begins as a single cell. For untold aeons all the life there was consisted of unicellular organisms; only very gradually were more complex forms evolved. Today, though there are a vast number of complex organisms, there are also tens of thousands of unicellular species, some of which may have remained unaltered since the dawn of life.

If life holds somewhat precarious beach-heads on the Earth's surface, what are its chances of clinging to them, so to speak, should an enemy attack in force – a purely physical enemy? – that is to say, should the limits within which alone life can survive become still narrower? We know, of course, that earthquakes, floods, volcanic explosions, fire, disease and other ebullitions of nature can take a heavy toll of life, and that with all our knowledge there is not very much we can do about it. But unless there is a vast increase in the number and violence of these assaults – and of that there is as yet no sign – they can never utterly destroy life. Indeed, they barely even check it. But in other respects the position is much less secure. For example, a very slight alteration in the composition of the atmosphere eight or nine miles above the surface of the sea – not very much higher than the top of Mount Everest – would see the end of life on this Earth.

Ultra-violet rays are death. They are given off by the sun continuously. A small amount of ozone, mixed with the ordinary gases of the air in the ionosphere (a layer lying immediately above the stratosphere), absorbs nearly all the ultra-violet rays. Very few ever get through to the Earth. But if this ozone was not present, or if there was a marked decrease in its amount, most of these death rays would get through, and on a sunny day exposure of our skins for a few seconds would mean its destruction, with all the disastrous consequences (for us) which that would inevitably imply. We should be scalped all over.

On the other hand, should there be a big *increase* in the amount of ozone in the ionosphere, so that *no* ultra-violet rays got through, we would probably all die, though more slowly, from lack of vitamin D, the sunshine vitamin! It has also been suggested that there might be such an enormous increase in bacterial growth under the influence of the increased supply of ozone, that man could not cope with it. The world would become as mouldy as a green cheese. We should all be choked with fungus spores.

Besides these effects, there might be others which no one has as yet envisaged; but whether harmful or not, it is improbable in view of the above effects that we should be able to appreciate them. As to *how* an alteration in the percentage of ozone might come about, we know too little about the ionosphere to hazard a guess. But it is hardly beyond the range of possibility. There are, of course, other possible ways by which life might be wiped out, quickly or slowly; and some of them would not involve any very drastic changes. Life can exist only within a certain range of temperature, which is not wide; in the presence of oxygen (diluted); and in the presence of water. Enough has been said to show that the harmony which has permitted life on Earth to evolve is perhaps unique in the whole universe; the scale might be tipped easily enough, one believes, with momentous consequences.

These things, however, are without significance apart from Man's consciousness. It is his own brain that embraces such thoughts; *he* is the audience who watches the drama of the world unfold. No wonder he feels elated! No wonder he feels he has dominion over the Earth! How consciousness and, more particularly, self-consciousness evolved in the first instance, it is not for us to say. When man is Man he is already a dimly self-conscious being. Let us therefore trace very briefly his cultural steps up the long ladder from the beginning to the present day, in so far only as his ideas could be translated into material culture. We may find that the main steps are very few, perhaps no more than six or seven, and that they are sometimes separated by centuries, even by millennia. Nor do we believe that the last bold step has been taken.

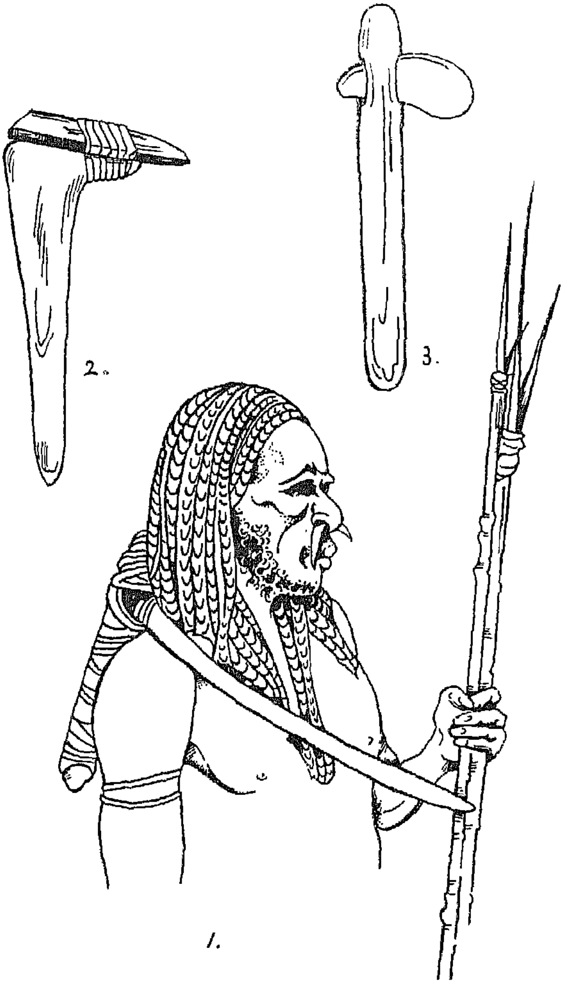
This, then, is the theme of the following essay; and it is worthy of note how long is the time-lag between one forward step and the next.

CHAPTER II

THE INVENTION OF CIVILIZATION

AS we go backward in time, the outline of Man and his story becomes ever more faint. Much of it has been completely erased. The few certain facts can be stated in a few words; the many theories in not so few. Speculation and argument flourish in the absence of knowledge and it would be unfair to omit the often conflicting theories of experts – unless one were oneself an expert with a pet theory! This the present author does not claim to be. Thus even of the faint uncertain past much can be written; while a full account of the later prehistoric and early historic periods, illuminated by research workers from many angles – anthropological, archaeological, geological, zoological, geographical, botanical, and others more direct – would fill a small library. If we peer down the dim vistas of prehistory, the road stretches out ever more featureless, with fewer lights ever more widely spaced. If we go back far enough, we must at last reach a common ancestor for Man and ape-man, for ape-man and ape. So far both have eluded us, but this we know: several species of Man – *Homo* – have inhabited this Earth in the past, have existed if not side by side in Europe, at least contemporaneously in Europe, Africa and Asia, and have doubtless come into conflict. War to the death followed. But though after thousands of years one species alone prevailed, signs are not lacking that the unluckier species were not completely exterminated, but rather absorbed. Even if only one human species spread over the Earth in late Pleistocene times – say 15,000-20,000 years ago

Warrior of Ifitamin, N.E. New Guinea.



(1) New Guinea native with a stone adze and spears. The man wears a hair-net and nose ornaments of boar tusks; (2 and 3) Neolithic stone adzes.

– isolation and differences of environment must have had some effect.

Civilization is Man's greatest invention. That it could only have been invented in certain favoured places, under certain conditions, by certain highly endowed peoples, is suggested by the fact that Australian, Fuegan, New Guinea, Amazon and many African tribes, as well as those of isolated islands, never knew it. They reached a certain stage of primitive culture and remained there – savages of the Stone Age still. Perhaps, however, it would be truer to say that some of these *lost* their civilization, having broken away from more cultured races, and steadily deteriorated in the wilderness.

Man did not become civilized merely as a result of existing. He strove for advancement. He went out and founded civilization. The conditions under which civilization could have been invented exist in comparatively few parts of the world. Other places were probably not inhabited till long afterwards. Yet, compared with Palaeolithic Man, even the Australian aborigines (though themselves living in the Stone Age) have advanced a little way. It is difficult to believe that Man could have invented civilization until he ceased to be nomadic. What the minimum conditions necessary for civilization to blossom really are, we do not know. Obviously, the available raw materials had something to do with it. But raw materials, however varied, abundant and accessible, are generally useless without special knowledge. They remain raw. A few, like timber, stone and even coal, can be used as found; but the vast majority must be treated before they can be of use to Man.

We may be sure that civilization was invented on the level plains, and that it required ample (if intermittent) water, a warm climate for the ripening of grain and the growth of fodder, with stone and timber for building not too distant.

It is interesting to note that all the earliest civilizations of the Old World lie within a belt whose approximate width is 30° of latitude. This belt is bounded on the south by the 15th parallel north of the equator, on the north by the 40th parallel. It includes great areas of arid plains country. Within it lie the southern ends of the European peninsulas, together with most of the Mediterranean basin, most of North Africa, nearly the whole Arabian coast, the southern Caspian region, north-western India, the Tarim basin of Central Asia, and the central and northern plains of China. Great rivers flow through all these regions. They include considerable areas of mountain and desert, which serve to isolate one oasis from another; but the desert regions were certainly fertile a few thousand years ago.

As to the New World, evidence has recently been brought to light that Man reached North America during the late Pleistocene period, 10,000 or more years ago; and here civilization, the germs of which were imported from Asia, developed under conditions and in regions different from those of the Old World. The Americas lacked iron, the wheel, the plough and the horse, when Columbus discovered them, so one may assume that Man reached the New World before these things were known in the Old.

The evolution of civilization has not been one of steady and continuous advance, and at no period has all mankind ever been at the same level of culture; nor is it possible that it ever could be so. At various times, when stragglers have been cut off from the main body (as happened often enough), deterioration has set in and another, cruder, civilization been established on the ruins of the old. Such lapses towards barbarism are common in the mountains of Asia; but they are of very recent origin. Nevertheless, while civilization was retreating on some fronts, it was advancing on others, and the net result, looking at the entire world, seems on the whole to be a general advance, though rather by fits and starts. The reason for this appears to be that for advancement on a broad front, civilization needs certain fundamental discoveries and inventions, and that these have been made only at long, irregular intervals, and in divers places.

A basic discovery is something far more than an improvement, or the further development of an idea. It enriches and rejuvenates civilization, giving to it a fresh impetus, a new meaning and a new direction. It makes a world-wide appeal, and does not remain the peculiarity of one culture; it illuminates barbarism itself, and becomes the heritage of mankind throughout the world. Whatever the many invaluable discoveries of the last 5000 years have done for civilization – and they have done much – only one or two have had a revolutionary effect throughout the entire world. Much of modern 'progress' is merely an improvement in technique, or the substitution of one raw material for another.

Primitive Man, like modern Man, feared *change*. It is easier, and pleasanter, to reform others than to be reformed oneself. The same is true of customs; the resistance of old customs to new ideas is immense. But the great forward steps brought such obvious improvement in Man's lot that they became irrevocable.

As an example of a first-rate idea whose significance it is impossible to exaggerate, let us take the discovery that the Earth is round and hence finite – a discovery so profound that it enormously widened Man's mental horizon, and paved the way for almost unlimited progress. Like the discovery of time, it was not made in a flash; rather it dawned slowly on men's minds, and was gradually accepted as the evidence in its favour became overwhelming. Credit for this astonishing thought, which directly contradicted the senses, is given to Eratosthenes, the Greek philosopher-geographer of 300 B.C. who first proclaimed it, though many others over a long period of time have had a hand in it.

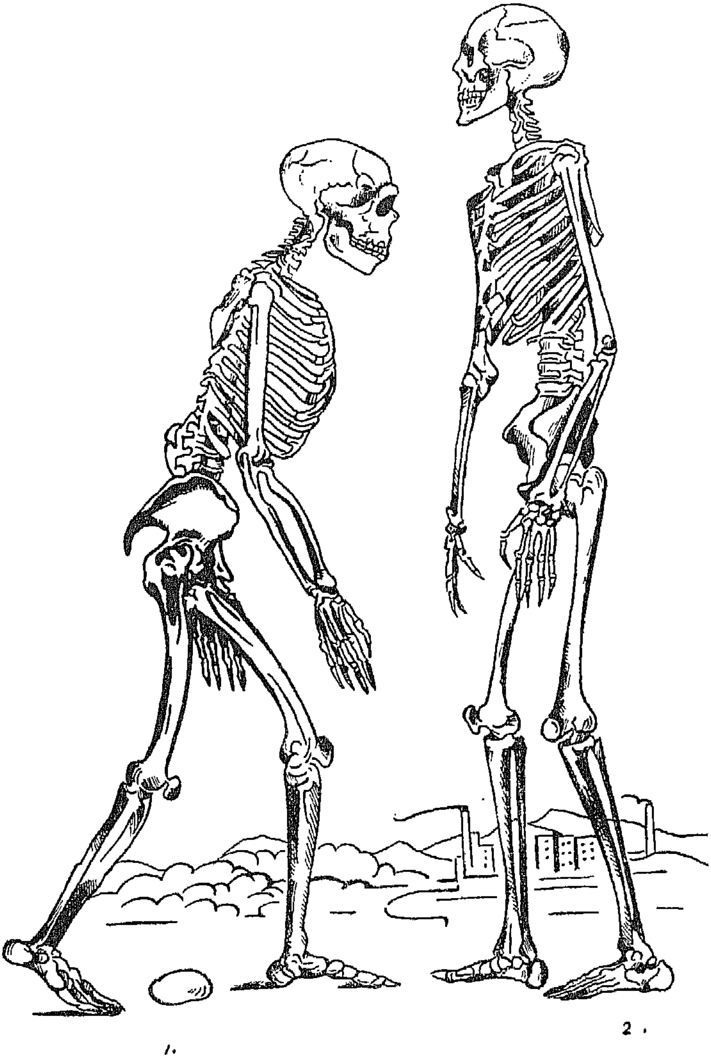
Before the invention of writing, cumulative proof of the Earth's shape was practically impossible. Tradition and folklore took the place of fact. Anything wonderful – and everything *was* wonderful in the dawn of scholarship, just as everything is wonderful to the modern boy in the West – was told and retold, and thereby became ever more wonderful. But writing had been invented 3000 years and more when Man first knew that the Earth was round; and having made the great discovery and pondered it for a thousand years, civilization, in the West at any rate, passed through a period of such mental darkness that one of the greatest discoveries ever made was ignored, or forgotten, for three full centuries, while Man groped once more in the blackness of the night in which superstition had engulfed him.

There can be no doubt, however, that all over the world, and at all periods, civilization has stagnated or retreated, as tribes and races forgot what once they had known. Most of the hill-tribes of south-east Asia, for example, are very civilized, and it is manifest that they are sprung from highly endowed stocks who were well versed in the arts, including the art of writing, which their isolated descendants in *their* Dark Age, have forgotten. It is not impossible that in the dawn of time even the discovery of fire was made and lost several times over.

It will be remarked that not one of the great figures of history, the founders of the world religions, the saints, the captains and the kings, benefactors and malefactors, gets so much as a mention in this book. Even the very few inventors and discoverers obliquely referred to remain anonymous, not merely because we do not know the name of the particular hero – because obviously for the majority of the footsteps we do not – but in order to emphasize that the greatest forward steps were made not by one man in a day, or even in a lifetime, but by many men in the course of centuries. Who, for example, *invented* writing? We shall never know. To dilute the drama of these material steps with the vague shapes of cloudy abstractions, however silver-lined, would weaken both. The footsteps described here are mostly solid achievements. They deal with 'things that you may touch or see', though I have strayed from the highway in order to discuss the origin of fire, the discovery of time and the recognition of power. Man did not develop his relatively enormous brain to no purpose. He may have needed several thousand years to learn how to make full use of it – Neanderthal Man had a brain no whit inferior to our own – but when he did learn, he quickly forged ahead. He made things of ever-increasing complexity and subtlety. He developed memory. He had ideas – ideas of justice, truth, religion and philosophy, not to be represented by things, but capable of influencing his actions and of inspiring further progress.

It may be objected that the footsteps, based on material discoveries, are an arbitrary choice; that other discoveries and ideas might equally well claim to be basic. I do not agree. These alone seem to me to have moved mankind in general, directly or indirectly, nor do I think that any others have had the profound and lasting influence which these few have had. Their precise order is more open to argument.

Yet I may be wrong. It seems to me to be at least in part a matter of opinion, and others might make a slightly different selection – though none could deny the paramount importance of fire, the domestication of plants and animals and the invention of writing. But if the ideas developed here



Skeletons of (1) Neanderthaler (2) modern Man.

arouse some opposition, they necessarily arouse interest; and I ask nothing better.

I have excluded speech because I hold that Man was not Man until he *could* speak. Many times have I heard gibbons calling and whistling in the dark Burmese jungle. I remember the first time I ever heard them, in the mountains, thinking that I was back at the dawn of Man, with the first attempt at speech echoing round me. The several notes, their sequences, and what seemed like deliberate replies, were astonishing. Yet it was a long way from human speech. Even Neanderthal Man may have been little more articulate than that.

It would be possible to argue further that Man was not Man until he possessed the secret of how to make fire. But we must not forget that Neanderthal Man, who lived in north-western Europe till some 20,000 years ago, possessed fire before he vanished for ever. It is less certain that he could talk. Fire, however, is much more than 20,000 years old; Peking Man possessed fire in Asia half a million years ago. But the origin of fire is so fascinating a subject that I would fain make it the first footstep of all. One must begin somewhere, breaking into the long procession of life, and, as distinct from the ape-men who possessed fire, I propose to start with Man walking upright and able faintly to speak, a power which itself implies certain well-marked differences from apes, however anthropoid. But for tens of thousands of years before writing was invented, the early struggles of Man can only be guessed. Any conclusions from the scanty evidence are in some doubt. Over long periods of time, and across vast empty spaces, there was nothing to record.

CHAPTER III

YESTERDAY AND TODAY

MAN is old or young according to the scale by which we measure his life on Earth. We may measure this by years, which is the measure of each man's life; or by generations of a quarter century or so, which is the measure adopted by those chieftains who trace their descent back into the past; or again by the centuries of dynasties which, as history tells us, ruled over Egypt. By any of these measures we must use many units to convey some faint idea of the age of Man; and so Man appears old indeed. For today is not the twentieth century of Man's sojourn here; rather is it the thousandth century, or the ten thousandth.

But is this time scale the right one? Biologists are agreed that Man is descended from some creature which was not Man, but something simpler, something less specialized in brain power, more generalized in structure; in other words, that like all life on this Earth he has evolved gradually from a lower to a higher plane. This necessarily implies that he is still in process of becoming. Thus, since we know that evolution takes place very slowly, ought we not, perhaps, to measure Man's age against the evolutionary time scale, that is to say, the geological time scale? I think we ought to.

Then how young Man will seem! How untried! He goes forward with faltering steps, only to turn aside, to take a wrong turning, perhaps to retrace his route, even to retreat, before again plodding on. Nor can we even dimly realize how far he has yet to travel, since we do not know his goal.

If, then, one thinks of the age of Man in terms of years, the numbers of them, as we shall see, become too great for the mind to grasp. Periods of 50,000 years, rising by leaps to a million or more, mean nothing to us. If, on the other hand, we think of Man's age as a fraction of the geological time scale, that is, as a part of all the sediments laid down since Life began, we shall find that it is really a scarcely visible wafer. That is the dilemma; we have no familiar measure of time with which to measure the age of Man.

Nevertheless, most of us want to know 'how long ago' everything happened, whether it be the beginning of the world, the coal forests or the end of the Ice Age, oblivious of the fact that the coal forests, for example, lasted for millions of years, and that we may still be living in a pause of the Ice Age, as yet unfinished. A time scale – not a mere sequence of events, but actual dates – seems to be almost a human necessity. We need to think in terms of familiar units such as are used in history, and can with an effort be stretched back into prehistoric times, so many years ago. But the probable error, which begins immediately there is no written record, becomes greater and greater as we push back into the twilight of the past; and a probable error of a few score years or even a few centuries in our dating of the post-glacial period may, before we reach Man's beginning, have swollen to an error of tens of thousands of years – an appreciable fraction of the whole time under consideration. A dated time scale is little more than a plausible guess.

He would be rash who committed himself definitely to a statement of when *Homo sapiens* first appeared in a raw world; but few people at present assign to him an age of much more than 25,000 years, which is only a minute fraction of the time required for the whole pageant of life on this Earth to unfold.

Ape-man is known to have lived in Asia, in Africa and possibly in Europe, upwards of half a million years ago; and

Neanderthal Man – *Homo*, but not *sapiens* – lived in Europe 20,000 years ago, and much later than that, right down to the Neolithic invasion which may have begun about 4000 years ago. These New Stone Age men, coming out of the enormous emptiness of the East into the chill north-western peninsula, found Europe occupied by Palaeolithic Man. They were far ahead of him in skill, just as the Old Stone Age men had been far ahead of the ape-men. And New Stone Age Man – *Homo sapiens* – proceeded to wipe out Old Stone Age Man – *Homo neanderthalensis*. But that the half-brothers overlapped in time is certain; that they overlapped in space, probable. A bald story, and a sorry one; the history of 20,000 years, more or less, stated in a few words.

Let us now turn to the geological time scale, which measures time, not by years – not by the swift revolutions of the Earth round the sun – but by the rate at which the mud carried down by rivers accumulates on the coastal shelf, and glaciers advance or retreat. A century is scarcely a large enough time unit for visible results. Silt accumulates layer by layer in the shallow seas at the rate of perhaps a few centimetres, or a few inches, in a century, and the layers are gradually compressed by their own weight.

Coming within the grip of forces which bend them up above the level of the sea, they presently help to form visible dry land. Careful measurements of the thickness of these compressed and stratified rocks, laid down from the time when land and sea could first be clearly distinguished, and rivers first flowed, have given discordant results. It has been computed that their total thickness, supposing the entire sequence to have been laid down complete in one spot, and supposing it to have remained horizontal, would have formed a cliff more than fifty miles high, reaching up into the ionosphere!

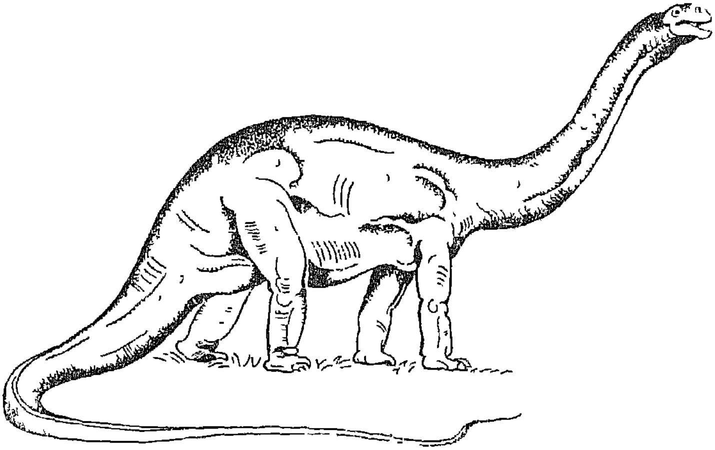
When we reflect that in one year a layer as thin as a piece of silver paper, or even of gold leaf, might be deposited, we shall begin to realize the vast lapse of time since the world was young. Nor does the beginning of sedimentation mark the beginning of the world, though it might mark the dawn of life.

Against this profound time scale the age of Man is but an episode. Life has been life, say biologists, for perhaps two thousand million years; their requirements (having regard to the extreme gradualness of change, so far as observation goes), can do with no less. But though gradual, given time, change is certain, inevitable, and evolution is sure; there is a limit to the age of Life itself.

Scarcely a million years, perhaps less than half of that time, is deemed necessary for the evolution of the highest and latest model – Man himself – from near-man, though it must be confessed that the frontier between Man and non-man is exiguous.

Throughout those long, dim ages when the queer-looking jointed trilobites, like uncouth woodlice, and the florid graptolites were creeping along the bottom of Cambrian seas; when the coal seams were accumulating in the warm foetid swamps of the world; when the sharp red sands of the Devonian age were covering the gristly skeletons of the earliest fishes; during the countless millennia when the pale, sticky ooze was settling down bed upon bed to form in a later age the white cliffs of England and of France; and during the untold aeons of the early Tertiary period, when those terrible monsters of the Age of Reptiles, which for forty million years had dominated the world, were vanishing like smoke, never to return; to the dawn of a pleasantly warm moist world climate in which everything grew luxuriantly again, there was no recognizable sign of Man, still distant millions of years. The long Tertiary Age drew to its lovely Indian summer's close. It was idyllic; so idyllic that nothing seemed to happen. The world, time itself, stood still – the hush before the dawn. The sun-bathed landscape, rich with luxuriant flowering trees, lay mellow in the warm scented air.

Nevertheless, faint signs of a change were not lacking. Nothing, least of all such bliss (though there was none to appreciate it), continues the same for ever. The summers were beginning to grow a little shorter, a little cooler; the winters a little longer, a little harsher. Slowly, slowly, yet with a terrible persistence, throughout the whole northern hemisphere – helped, it may be, by the Earth wobbling ever so slightly on its axis, like a top losing its spin – the Ice Age dawned. That dawn alone lasted for thousands of years, while the Earth perhaps tilted its axis towards stars other



Brontosaurus (thunder lizard), about 75 feet long than Polaris, in slow precession. And following the dawn came the evening and the long bitter night. . . .

The Ice Age lasted a million years, more or less. It was towards the close of this austere time, during the last of the warm interludes between glacial climaxes, known as interglacial periods, that Man appeared in central Europe, wandering out of the void, sprung, perhaps, from the dark heart of Africa; perhaps – and indeed more probably – from the womb of Asia, though still we are by no means sure of where was the cradle of early Man, or even whether there were not one, but two or more such cradles. The origin of Neanderthal Man, his earliest home, and his migrations, is still obscure; but we know that previous to his appearance more than one species of sub-man or ape-man roamed over parts of the Old World. There were two or more species of Palaeolithic Man also; it would have been remarkable had there not been. One may conjecture that Man and ape-man lived side by side in some parts of the world, though not, perhaps, for long.

Whatever the origin of Palaeolithic Man, whence derived and whither he went, it is certain that Neolithic Man rediscovered Europe for himself, stepping over the eastern horizon. He too appeared not once, but several times – that is, he came in waves; and the scene he gazed on four or five thousand years ago was not unlike modern Europe in form and in its vegetation and animal life. The same trees and birds and mammals as greeted him greet us on the continent today, though not always in exactly the same places.

That is not quite true for Palaeolithic Man; still less is it true for ape-man, who lived during the early Ice Age. At that time the cold fluctuated, increased and decreased again, while the glaciers grew longer or shrank back. There were, as we have said, warm, or at least temperate, troughs between the cold wave crests. The entire glacial age consisted in Europe of alternating periods of Arctic cold and genial warmth; in Africa, of alternating wet and dry periods. These periods, glacial and interglacial, varied, of course, in intensity, as they did in length; but each of them is to be measured in tens of thousands of years. During one of the warm interglacial periods, Old Stone Age Man appeared, hesitantly at first, while the ice slowly retreated over north-western Europe and the tundra again became green. This may have been 20,000 years ago, or even more; but not much more.

So Palaeolithic Man was established in Europe, and in western Asia too. But the short summer came to an end; the ice came on again, the cold increased, the glaciers grew longer, and Man himself fled south, ahead of the creeping cold; and with the next interglacial period – the present one – for we are living in it today – he spread northwards again. Then 4000 or 5000 years ago Neolithic Man appeared out of the East, and Palaeolithic Man retreated before him, even as ape-man had retreated before Palaeolithic Man.

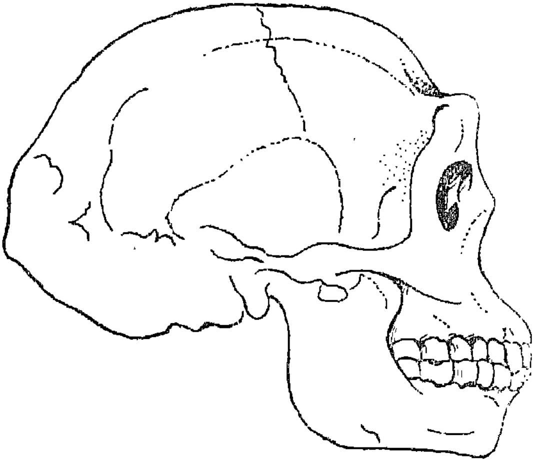
So Man's ancestors wandered restlessly and uneasily through the unfamiliar world of a hundred, or two hundred, thousand years ago – a world which even then was new by our geological time scale, and almost recognizable as the world of today.

We have said that Man was not Man until he could walk upright *like* a man. Thus our brief sketch of the foundations of civilization begins with a man not so very different in appearance from ourselves, who walks erect and perhaps talks. Perhaps he covers his body with the skins of animals he has slain for food. He goes about in families, man and woman, with several children; already two or three families band themselves together, forming the nucleus of a tribe.

There are two unique characteristics which immediately distinguish the most primitive of living men – be they Australian aborigines, Congo pygmies, Indians from the Upper Amazon, fuzzy-haired Solomon Islanders, or New Guinea cannibals – from the highest apes. One is his upright carriage, the set of his head on the spine; the other, his power of speech. Both were acquired, we suspect, gradually and painfully. *Both imply changes in bodily structure, different* from that of any other animal living or extinct.

Anthropoid apes – the gorilla, for example – can stand upright, and so for that matter can the bear. Anthropoid apes can also, in a sense, *walk* upright, though not without touching the ground with their knuckles to assist their balance; indeed, it is by virtue of their exceptionally long arms that they are able to walk upright at all. But this is not their normal mode of progression, though they are not truly arboreal animals.

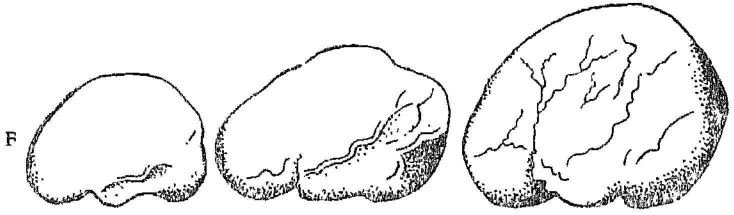
Not even anthropoid apes, however, can speak the most elementary words. Perhaps the gibbon comes as near as any living wild creature to conveying his emotions through his larynx. We may well be astonished at the range and variety of the gibbon's cries, at least the first time we hear him. Yet regarded as speech, his performance is not impressive. But there was a time, if we go back far enough – only yesterday in the geological time scale – when a creature which was neither so primitive as apes, nor so advanced as Man, lived on this Earth. We call him sub-man or ape-man. One species of ape-man lived in Java, another in China, a third in South Africa. Perhaps some day we shall know much more about these half-human, half-ape creatures which lived, and died out, hundreds of thousands of years ago; and about other species of ape-man which lived in those far-off times, as yet unknown. They were, as I have said, not men – neither *Homo* *sapiens* nor *Homo* at all – they were half-men. They walked scarcely upright like men, though not with complete confidence. Their gait was, we may suppose, a shuffle rather than a walk, a slouching gait, a sinister and furtive shamble, somewhat uncertain of itself. Did these sub-men talk? If so, it must have been in guttural voices, with hesitation and difficulty, making no more sounds than would be sufficient to convey their most urgent needs to one another.



Skull of *Sinanthropus* or Peking Man. Less than one-third natural size (after F. Weidenreich).

I say 'with hesitation and difficulty'. It is not to be supposed that the gibbon, whooping and whistling in the tree tops in the silver dawn of a winter's day, has any difficulty with the joyous sounds he utters; but neither do we maintain that the gibbon 'talks'. The earliest speech must have been a matter of profound difficulty, needing thought and continuous effort.

How do we know that these sub-men could not talk effortlessly, as we talk, and so, quite apart from other ape-like characters, were not yet quite men? Speech consists of sounds of varying pitch, quality and timbre, and such sounds can only be made by an efficient instrument. The human larynx with its vocal chords is such an instrument, controlled by certain muscles which in turn are attached at certain points to the skull and jaw-bone in a definite way. The marks of attachment survive, although the actual instrument does not. Given the skull and jaw-bone, a skilled anatomist will work from the bones to the muscle scars, from the scars to the muscles themselves, and from the muscles to the missing instrument they operated; that is to say, the larynx. Therefore it is possible to say whether or not the owner of such a jaw-bone could have been articulate or not. Further, the skull alone will tell an anatomist much more – about the status of the creature, about its brain power, human, sub-human, or non-human; and it seems certain that before we have dug very far back into the history of the Primates (which Order includes Man, sub-man, and man-like or anthropoid apes) we come upon a creature who was not quite Man, who was inarticulate, and who shuffled uncomfortably along, making a conscious effort to keep his balance. For balance is normally unconscious, controlled by the inner ear, which is not subject to the conscious will.



Side view of a cast of the inside of the brain-case of chimpanzee, *Pithecanthropus* and *Homo sapiens*. F. Front part. About one-sixth natural size. See also illustration of skulls in Chapter IV.

Still further back in time we must inevitably arrive at an even more generalized type, a more primitive creature from whom our sub-men, or some of them, were derived. Unfortunately these skulls of Man's earliest ancestors are extremely rare. They turn up, far apart in space as in time, at long intervals – in Java, in England, in Rhodesia, in China, but never yet in the New World, which has probably been inhabited by Man for no more than 20,000 or 25,000 years. There are no more valuable pieces of evidence to the prehistorian than these rare relics.

So we continue further and deeper into the unwritten past, back and back through the cycle of those bleak ages, known as the Quaternary Ice Age, perhaps a million years ago, when north-western Europe looked not unlike Greenland does today, to a time when creatures who were not even sub-men, who were not men at all, and who spent some of their time, perhaps, in the trees or on cliffs, lived in the world. This was before the Ice Age. What is desert today was rich pasture or forest then; round the coasts of Europe much of what is now sea was dry land. The evolution of Man from sub-man, and of sub-man from a creature who was in no way man, certainly took many hundreds of thousands of years.

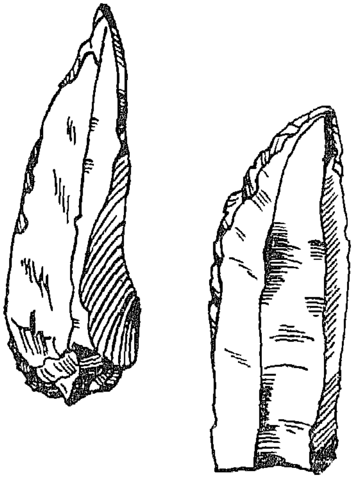
After the lapse of this long period – long, as we have said, if measured by our ordinary everyday time scale, but short, or rather negligible, as the geologist measures time – there came into existence somewhere in the ancient world, perhaps in one, perhaps in more than one, place, certainly in Europe and Asia – Man.

He was Man, as was pointed out at the beginning of this chapter, in that he walked upright without difficulty, and talked, though perhaps not very clearly. He had no experience and very little knowledge. He had no sense of time. But he had a brain, enormous compared with the brain of any other living creature. Far as it had developed, it was – and is – capable of further development.

It is clear that until we can assign some age to Man himself and say whence he derived, we can hardly hope to say with any precision how long ago he discovered this or invented that, in the prehistoric era. He may have discovered how to make fire, for example, 100,000 years ago or 250,000 years ago. We do not know, but it can hardly have been less than 100,000 years ago. Does it really matter, though? At least we can be *reasonably* sure of the order in which Man made the chief advances, and we have some idea of the lapse of time between each advance. Yet the subject is a fascinating one.

No *direct* ancestor of Man – *Homo sapiens* – has ever been found. All his known ancestors are once removed or more. In Asia and Africa several distinct species of *Homo* lived; but from none of these is Man descended. No common ancestor for Man and ape-man has ever yet been recognized; but that such an ancestor will some day be discovered somewhere seems probable. Ape-man was exterminated a long time ago, though not before he had discovered fire. Perhaps his victor had discovered how to *make* fire, in which case his superiority was overwhelming.

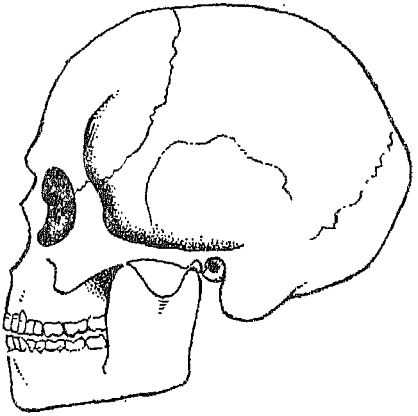
Palaeolithic Man of 100,000 or 200,000 years ago – that is ape-man – had knowledge of fire; he probably discovered more about it in the course of the next few thousand years, long before Neolithic Man reached western Europe from Asia; for Neolithic Man did not reach western Europe till close on 2000 B.C. We may be sure that *he* knew all about fire. At the time he entered Europe he was so far superior to Palaeolithic Man that he gradually exterminated him, or drove him into remote corners; but not, perhaps, before he



Flint implements of later Palaeolithic hunter.

had interbred with him. Or did Palaeolithic Man long survive in a few hidden spots in north-western Europe? If he did survive, the shores of the Baltic would be the most likely place to find him. Have not the Prussians more than a trace of Palaeolithic Man in their makeup? And the Russians?

So Man, *Homo sapiens*, the finished product of the age, stalked upright across central Europe, devastated by ice, some 10,000 or 15,000 years ago, still Stone Age Man, savage, coarse and uncouth, living a precarious life of which we in the twentieth century after Christ can have little notion, so different was it from our own; yet not so very different from a few primitive tribes still living in a few remote corners of the world. He drove before him Neanderthal Man, who was as strange to him as a Congo pygmy would be to an Englishman. This New Stone Age Man knew how to make fire; he probably wore animal skins. Perhaps he painted or scarred or otherwise disfigured his



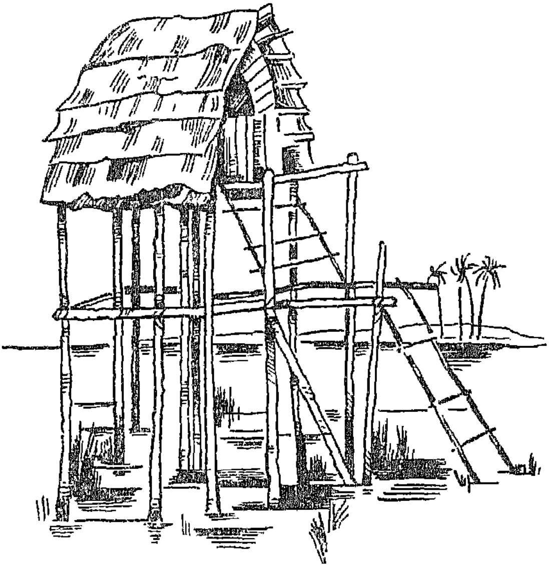
Skull of Cromagnon type dating from Aurignacian times. About one-quarter natural size.

body. He could, one supposes, talk, after a fashion; and he possessed beautifully shaped flint tools wrought with great skill. But he knew nothing of the simplest machine, had no knowledge of the world in which he found himself, had no ideas beyond the craving of the appetites. He was probably ignorant of time, and was without memory. He was a hunter who lived for the moment. And yet, in appearance he was not unlike ourselves. His proportions and the size of his head, at least, were very like our own; and his framework or skeleton could scarce be distinguished from a modern skeleton. If you dug up such a skeleton, you would unhesitatingly say that it was that of a *man*.

It would be highly instructive could we find more remains, especially skulls, of primitive Man – of Neolithic and Palaeolithic Man – from all ages and all regions where such could have existed; and assuredly many more skulls *will* be discovered, and the details of the long-short story gradually filled in. Possibly new species of Man and of sub-man will be brought to light.

But now that the whole world has been searched for types of mankind, and for traces of early Man in living primitive races – bushmen, Australian black men, pygmies in Central Africa, Sakai in Malaya, and so on – might it not bring better results if we searched patiently through *civilized* races for primitive characters which may crop up very rarely, but nevertheless *do* crop up occasionally? What about the teeming cities of the modern world? If one person in a million exhibited some unmistakable Neanderthalian characteristic, that would be something to the good! Unfortunately not one person in ten million would recognize such a characteristic when he saw it!

The Palaeolithic age, that is, Palaeolithic *culture*, was coming to an end in Europe about 4000 years ago – in 2000 B.C., or thereabouts. It was succeeded by the Mesolithic culture, which may have lasted, in Europe, for 500-1000 years; and that in turn was succeeded by the Neolithic culture. This culture was not indigenous to Europe, but was brought in from beyond the Caucasus. Now men are beginning to make settlements, to build houses and erect stone circles, to bury their dead in barrows, to domesticate animals and plants. Civilization is being born.



In Europe, Stone Age men built their huts on wooden piles along the borders of lakes.

Let us try and fathom, then, how and in what order Man took those momentous steps forward which have brought him to his present-day uncertainties and perplexities. But first we will discuss that most dramatic of all discoveries, the prehuman discovery of fire.

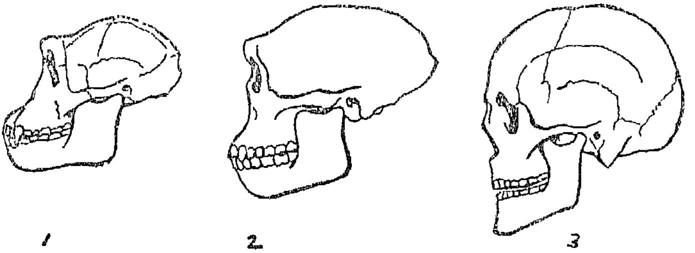
CHAPTER IV

THE DISCOVERY OF FIRE–I

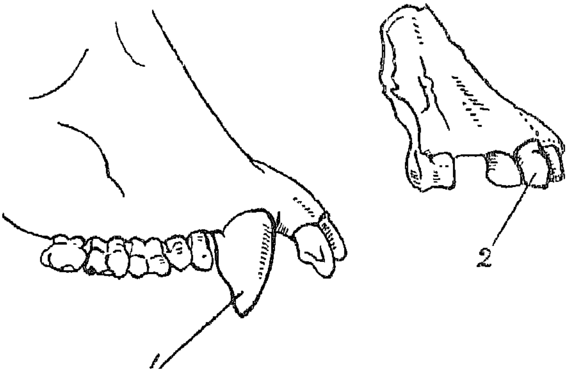
UNQUESTIONABLY the most startling discovery ever made was the discovery of fire. But was he *Man* – this early discoverer? Or was he just ape-man? Did Man when he first made his bow on the world stage, unmistakable *Man*, already know the secret of fire? Did he, in fact, discover fire because he was the intelligent, self-conscious, rational creature we call Man? Or did the fact that some ape-man stumbled upon fire serve to confirm the dawning possibility that he was already on the way to manhood, and speed his progress?

We have already noted that before the appearance of true Man in the world, more than one species of ape-man existed. Over a period of time, in some parts of the Eurasian-African land mass Man may have lived side by side with ape-man – not necessarily on good terms, though it is conceivable that they interbred. If Man and ape-man were contemporaneous, which of them discovered fire?

Was fire discovered more than half a million years ago, by ape-man? Or less than fifty thousand years ago by Man? Or perhaps somewhere between these two periods by Man who was neither half ape nor yet wholly wise? For consider: if Man acquired his modern jaw-line and regular teeth – teeth which have neither the aggressive canines of cats and monkeys, nor the prominent incisors of rats and rabbits – through a marked preference for cooked meat rather than raw flesh, as has been suggested, then we must conclude that he has been cooking his food for a long time. No mere 20,000 years would suffice for the change-over from the prognathous ape muzzle to the modern stream-lined jaw. However rapid human evolution may have been – and it may well have been more rapid than evolution in general – a few millennia would hardly be enough time in which to exchange the large canine teeth, sloped-back forehead, and massive muzzle of ape-man ancestry, for the even teeth, vertical forehead, and slim jaw of Man, with all the muscular alterations which such a change implies: in short, to remodel his face.



Skull of (1) chimpanzee, (2) *Pithecanthropus* (Java ape-man), (3) *Homo sapiens* (after F. Weidenreich).



Right upper jaw-bone with canine tooth of a fossil *Australopithecine* (Southern Ape) (2) compared with canine tooth of a male chimpanzee (1). About half natural size.

We may note, however, that the modern great apes live chiefly on roots, fruits, leaves and other vegetable parts, although many monkeys – for example, the little Rhesus monkeys so common along the banks of hill rivers in Assam – include crabs, shellfish and other animal morsels in their diet. All the more strange is it, therefore, that they should have such large canine teeth. But that is by the way.

If, then, fire was discovered by Man, or even by near-man, who had lingered on in remote places, despite the presence of all-conquering Man, fifty or a hundred thousand years ago, we must admit that change of diet alone had little to do with the changing shape of the skull, and other anatomical details, the main trends of which must have been outlined many thousands of years earlier, even though Man throughout that time continued to eat uncooked vegetable food.

The only alternative would be to antedate the discovery of fire and the common use of cooked food. Such a revolution in diet, and in the methods of acquiring it, might, one supposes, have been responsible for starting the anatomical changes which seem to have followed. No doubt several causes acting and reacting on one another contributed to the new model, but it was not likely to have been brought out in a hurry.

However, it is perhaps idle to speculate along these lines, since it seems certain that ape-man *had* some knowledge of fire half a million, maybe even a million, years ago; and this fact must greatly have influenced his evolution towards manhood. For who but he possessed fire?

Though early Man – such as the ape-man of Java, the earliest man-like animal of which remains have been found – *used* fire, he may not have known how to produce it. The art of *making* fire at will might have come much later, and we shall be right to distinguish between the two ideas. They are, indeed, as I shall attempt to show presently, two steps which may easily have been separated by many tens of thousands of years, during which Palaeolithic Man was wandering all over the habitable world, meeting with a variety of conditions.

If, then, we accept it as fact that fire was known at least to some groups of Palaeolithic Man almost a million years ago – and the evidence for this is the finding of charred animal bones alongside the skull of Man himself – but that the *making* of fire was not known till the coming of *Homo sapiens* or other true Man some 25,000 years ago, we can understand how cooked food might have played a big part in human evolution. It would not be necessary for Palaeolithic Man to know the secret of raising fire in order to cook his meat, if he either had frequent access to sources of fire, or, having at infrequent intervals obtained fire, he managed to keep it burning. And that, as we shall see in a moment, is the difficulty.

On the other hand, there is no proof that ape-man, who almost certainly *did* possess fire, did not also possess the secret of raising it. Nor is there any proof that he did. If he could raise fire whenever he wanted it, he would surely cook his food; and if he could *not* raise fire at will, nevertheless he *might* have cooked his food, gradually exchanging a diet of berries, roots and fruit for an animal diet.

We may safely date the invention of writing, in its finished shape, to 5000-4000 B.C., and the domestication of animals and plants to 10,000-8000 B.C.; but the discovery of fire can hardly be put later than about half a million years ago, and may have been considerably earlier. And whereas writing was invented by modern more or less civilized Man, and the domestication of animals and plants was achieved by modern Man well on the way to becoming civilized, fire was discovered by quite a different animal who could not yet talk, long before the advent of undoubted Man. Nevertheless, had ape-man not discovered it and handed it on to his successors, there might have been no civilization at all. For civilization without fire is unthinkable.

Were you to meet this bold creature who made so daring a discovery, you might not – indeed, would not – call him Man, for he is very strange, and no doubt terrifying. Perhaps if you are well acquainted with the African gorilla or the Asiatic orang-utang, you might regard him as some nightmare ape, though with a rather more human appearance than any ape you ever saw. Indeed, it is the half-human look of him which would be most horrible. Let us try and picture him, however imperfectly, however vaguely, as he comes shuffling and slouching down the road towards us. In the dusk he is alarming. He is rather above than below middle height as we judge it, broad in proportion, and he carries his head – which is sunk deeply between a pair of massive shoulders – tilted somewhat forward like a man in a dream who is not looking where he is going. But the most striking thing about him – were you able to watch him closely, being yourself hidden – is his *thickness*, the great depth of his chest and of his trunk. He is long-armed too, though his thighs are sturdy rather than long (he is slightly bow-legged), and so looks out of proportion. And as he slouches along with a slight roll – for he is not well balanced, nor nimble – he peers to left and right from beneath shaggy brows.

If his general build, massive and rugged, and his almost, not quite, upright carriage, are near-human, his face and the shape of his head (if you caught sight of them) suggest some frightful ape, rather than a man. The nose is flattish, with wide negroid nostrils, the forehead, what there is of it, puckered, short and sloping, the eyes somewhat close together and half hidden beneath the tremendous brow ridges. But the most forbidding feature is the massive, rounded jaw, thrust aggressively forward like a muzzle (for he has no chin), and the large 'eye'-teeth, which give this dumb creature a perpetual snarl. And his expression – if he can be said to *have* an expression? Well, you would look in vain for anything which would give you a moment's confidence in his presence; rather would you see suspicion, brute reason and perhaps fear, graven on that tombstone countenance. Add to all this that the creature would be more or less covered with matted hair, reddish or perhaps auburn, and it will be agreed that such an apparition, did we meet it padding down a dark lane at dusk, might well strike terror into us for its sheer grotesqueness, so like, yet so unlike, ourselves – a monstrous caricature. Nevertheless, this creature, or something not unlike him, is believed to be early Palaeolithic Man, who possessed fire. . . .

What, then, do we know for certain about the discovery of fire? Almost nothing! We know that early Palaeolithic Man used fire for warmth and for cooking, because the results of fire have been found with his remains. It was used by those strange creatures, more human than ape, yet not very human either, who hundreds of thousands of years ago lived in South Africa and in China. Palaeolithic Man – there was more than one species, traces of which have been found far apart in space if not in time – *possessed* fire. But had he control over it? More important, perhaps, did all races of Palaeolithic Man even possess it? Was the knowledge of fire spread over the whole inhabited world from the beginning?

When Neolithic Man entered Europe, five, six, or possibly seven thousand years ago, he brought fire with him; but whether he brought it from Africa or from Asia is much less certain, though we have seen that fire had been known in both continents for hundreds of thousands of years and, for all we know to the contrary, in other parts of the world also.

Possibly the Old Stone Age man of Europe – Neanderthal Man, as we call him – went down before fire and stone. Possibly the newcomer – *Homo sapiens* – taught European Man the secret of fire; but it is much more likely that it was after all no secret. One can hardly believe that Neanderthal Man had been living in chilly, clammy Europe for thousands of years, stretching back into the Ice Age, without benefit of fire. But again, Neanderthal Man, too, may have *possessed* fire, and yet not known the secret of how to raise it; and it was *that* secret Neolithic Man may have taught him.

Yet if Neanderthal Man already possessed fire when the Neolithic invasions took place, he either had discovered it independently, or learnt about it from some other man than Neolithic Man. And if two peoples, in very different stages of culture, could each discover fire, why not more? Ideas could only be spread by people carrying them about.

If Neolithic Man brought fire to Europe, whence did *he* obtain it? As stated above, we do not know whether he had migrated from Africa or from Asia. Perhaps from Africa via Asia – even in those far-off days the march of Empire seems to have been westwards! But whencesoever he came, he had not grown up in a day. He himself inherited fire from an earlier ancestor; and it is not impossible that during the many thousands of years fire has been known in the world, its inheritance has been passed from tribe to tribe, almost as part of the order of nature. It is significant that most of the great finds of prehistoric Man, right down to Broom's recent discoveries of ape-man in South Africa (which some experts believe to be a million years old), are associated with evidence that he possessed fire. But how miserably few are these discoveries of early Man compared with what must have been his actual distribution over the Old World! It is certain that many more such discoveries will be made in the future, and it will probably be shown that not every race of ape-man possessed fire; or at least not proved that all of them did. There is no proof yet that the Javanese ape-man, oldest of all known ape-men, had any knowledge of fire. And this brings us to an interesting point.

If we consider the kind of country which ape-man inhabited, we may get a valuable clue to the origin of fire. The living great apes inhabit evergreen rain forest, or tropical jungle, and it is inconceivable that fire could have been discovered in such incombustible surroundings. Not till he emerged from the dark, damp forest into the open sunlight could ape-man have discovered fire; nor *was* he ape-man until he had left the jungle behind him; rather was he ape.

On the other hand, semi-desert conditions are no more suitable for fire than is evergreen rain forest. The vegetation of semi-desert, besides being widely scattered, is more or less succulent, and far from inflammable. Those regions of the Middle East where the earliest known civilizations have been found, are unsuitable for the discovery of fire.

As will be realized immediately when we consider the natural occurrence of fire in the world, the only type of country where early Man could have learnt about fire would be savannah or 'bush', that is, open country covered with high grass and scattered deciduous trees and shrubs, with a fairly heavy rainfall concentrated over a short period, followed by a long drought. Such savannah is not uncommon in Africa, though less common in Asia. It is in such country that the search for early Man should be made, although, as Leakey has shown, there have been changes of climate in Central Africa within the human period.

The story of how an animal who was not human came to possess, a million years ago, what no living animal possesses today – the knowledge and use of fire – is likely to prove a difficult one to unravel. Meanwhile, I shall indulge in a certain amount of speculation on this theme, in order to arouse general interest in what is undoubtedly a fascinating problem.

Under modern conditions fire is so much a part of our daily lives, and is so quickly and easily called up with a box of matches, that a world in which fire did not exist at all, or even only rarely, seems almost incredible outside a world of ice or of perpetual rain. It is certainly hard to conceive, until we ask ourselves a simple question: what fire, apart from Man, is there, or was there in the world ever? And the answer, one must admit, is equally simple: natural fire is *rare*.

We must now ask another difficult question, even more difficult, perhaps, than the one posed at the beginning of this chapter: did Man, or sub-man, discover fire by accident, or was it planned as the result of observation, thought and experiment?

The answer may be, both; the *getting* of fire being planned, the *making* of it accidental. Though we may never know the right answer, that is no reason why we should not argue so interesting a problem, in the hope of arriving somewhere near the truth. We will discuss the getting of fire immediately, the making of it we will leave to the next chapter.

First, let us inquire into nature's efforts to make fire, from which ape-man, perhaps after long observation, might learn something. That is to say, supposing this Earth to be uninhabited, what fires would an observer outside, casting his eye over the whole Earth, see? Fire is so much an everyday sight that an objective view of it has become difficult. A world in which it is a rare phenomenon seems fantastic. Let us, however, ask ourselves soberly where, and under what conditions, does *natural* fire occur? Where could ape-man, a creature with dawning intelligence, in the course of his wanderings see fires burning, and thus glean his first hazy ideas? Volcanoes furnish almost the only natural fire, although a volcano is not truly a 'burning mountain', since nothing burns but the gas emitted from the vent. Volcanoes, however, though not rare, are not common either; at least, they are confined to definite parts of the Earth's surface. Millions of people today have never seen a volcano, let alone an active one in process of eruption; but also millions today who have never seen a volcano have seen pictures of them, perhaps motion pictures, and read accounts of volcanic eruptions. Though volcanoes are widespread, they are far from universal, and vast areas of land are, and perhaps always have been, non-volcanic. And though they are a widespread source of natural fire, they are not the only source. Before we discuss the possibilities of Man learning his lesson from volcanic fires, let us see if there is any alternative; where also might he learn the hard lesson? What other sources of natural fire, or phenomena which might cause fire, do we know of?

The commonest, as well as the most universal, is lightning. Thunder storms may occur anywhere, and at any time of the year; and though certain regions seem to be noted for the frequency and severity of electrical storms, while other places are comparatively immune, no part of the habitable world is altogether free of them. Thus, if lightning can start a fire, it would seem as though early Man anywhere in the inhabited world might have seen fire, almost as certainly as he must have seen lightning itself. But though lightning can, and does, start fires, in certain parts of the world, special conditions are necessary. It could never set fire to evergreen rain forest, for example. When a tree is struck by lightning, it is often split, or even splintered as though by a heavy blow; or its top is broken off, or a strip of bark torn from the trunk. Rarely is it, in most parts of the world, set on fire. So swift is the stroke that there is no time for the wood to catch alight; just as a safety match will not ignite the match-stick unless it is first impregnated with mineral oil, although the explosion of the head produces a hot flame which lasts an appreciable time. However, Frazer says that in the violent thunderstorms which accompany the end of the dry season in Central and Eastern Africa, it is not uncommon for lightning to strike and ignite the forest, from which the fire soon spreads, till a great conflagration rages. The coniferous forests of North America are all too often set on fire by lightning. In grassland, too, under suitable conditions, during the dry season, lightning can easily start a fire, and such prairie fires are not rare. But unless fire resulted, primitive Man would not connect lightning with the blazing, crackling and smoking of a prairie or forest fire. He would be right in one sense; for lightning is not fire – combustion – though it may cause it. The two manifestations appear to him entirely different – as indeed they are – and disconnected. Thus there are serious objections to the theory that early Man may have learnt about fire as a result of seeing the effect of lightning. One dare not summarily reject the possibility, but though attractive, it is not a very plausible theory, if only because the areas where the vegetation is most likely to have been fired by lightning were probably not the areas inhabited by early Man. But, of course, the climate may have changed, and with it the vegetation. Moreover, as already noted, the discoveries of early Man are as yet far too few on which to found generalizations.

Almost the same objections apply to meteorites as a source of fire, except that meteorites capable of starting anything are far less common than thunderstorms. Meteorites of any size – apart from the millions which daily enter our atmosphere and are burnt up before they reach the Earth – fall on land only at comparatively rare intervals; far more, probably, fall into the sea. Nevertheless, a certain number *do* strike the Earth. And with what result? Either the meteorite 'explodes' above the earth, creating an immense blast, or on impact it makes a big crater, which is to say, it buries itself in the ground. What it does *not* do, apparently, is to start a fire. Thus the famous Tungus meteorite, which exploded over Siberia in 1908, flattened and to some extent charred the forest for nearly forty miles around; but no fire resulted. Even the 1000-ton meteorite which fell near the Pacific coast of Siberia in 1947 and exploded at a height estimated at five miles, though it rained fragments to Earth, only made a number of craters.

A meteorite, before it reaches the Earth, is red-, or rather, white-hot, and generally more or less plastic, if not gaseous. But whether it explodes in the atmosphere or buries itself in the ground, in neither event is it likely to set fire to anything. And yet, a white-hot meteorite falling into dry forest or grass *ought*, one would suppose, to ignite it. Some of the charcoal layers found in prehistoric settlements in Europe might have been caused by meteorites charring the vegetation. One suspects, however, that contact is all too brief to ignite anything less combustible than gunpowder, the wind raised by the rushing mass blowing away all loose material which might serve as tinder, and sometimes, as we know, flattening out whole forests.

Three requirements are needed to produce fire: a source of heat or energy such as a blow, to start or promote combustion, tinder to be ignited, and oxygen. The source of heat itself need not be near, so long as it can raise the temperature to the required pitch – the sun's rays, concentrated by means of a burning glass, are enough, though the sun itself is 93,000,000 miles away – but it must be applied for an appreciable time. That is why lightning, at a temperature high enough to melt most metals, often does not set anything alight. But lightning, we know, *can* cause fire, and it may be possible for a meteorite to do so also. According to Frazer, the Andaman Islanders believe that meteorites are 'lighted faggots hurled into the air by the malignant spirit of the woods', which suggests at least the possibility of fire through this means, though the evergreen jungle of the Andamans is certainly the very last place where one would expect a meteorite, lightning, or any other source of heat, to start a fire!

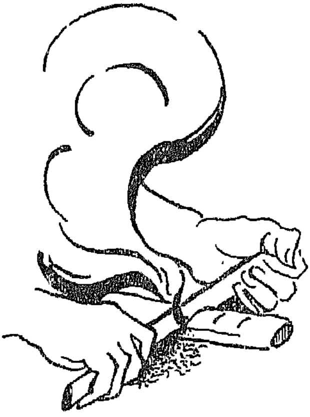
Other big meteorites known to have struck the Earth fell in Arabia and in Arizona, both desert or semi-desert regions. The former appears to have been sufficiently hot to fuse silica and form glass beads, just as a lightning discharge in sand has formed small glass tubes in South America, as recorded by Darwin. If, then, both lightning and meteorites fail to satisfy our demands for fire-raising, of which primitive Man might have availed himself, let us examine the claims of volcanoes a little more closely. Even in historic times volcanoes have played a fearful part in religion. Human sacrifice has been made to them by the simple process of throwing victims alive into the crater of an active volcano, to appease the anger of the gods. The largest active volcanic crater in the world is that of Kirauea in Hawaii, an immense cauldron of molten rock whose thunderous bubbling can be heard far off. At night the sky above this clanging hell is red as blood, lit up by the flames of burning gas which, in escaping, churn to fury the guts of the Earth.

But long before Man had become civilized enough to offer human sacrifice to the gods, away back in prehistoric times when his main efforts were directed to keeping himself alive, he must have been dimly aware of volcanic fires, hot springs, and the earthquakes associated with them. One of the places where volcanoes occur, and which were certainly inhabited by Palaeolithic Man 10,000 years ago, and possibly by sub-man ten times as long ago, is the Mediterranean basin. In those distant times Etna and Vesuvius were probably at least as active as they are today. Further east some of the Greek islands were volcanic. Another region where volcanic fires, if asleep for the last 2000 years, were wide awake at the time of which I write, is Asia Minor. Here, in Cappadocia, is Mount Argæus, a huge volcano 13,000 feet high, its brow bound with snow. On its slopes in those far-off days burned perpetual fires. Another volcanic area in south-west Asia is Lyddia. There were civilized communities in Asia Minor 6000 years ago, and before that Palaeolithic Man too must have lived here, and would certainly have known of this famous volcano. North of Baku, on the shores of the Caspian Sea (one of the regions known to have been occupied by Neolithic Man), everlasting flames burn above the petroleum beds – perhaps an even safer and surer pointer to fire than a stream of red-hot lava. In that region, which may well have been the cradle of the human race, Palaeolithic and Neolithic Man had no lack of opportunity to learn the secret of fire. Other parts of the world may also have been inhabited at that time, either by Man or by ape-man; these early humans or sub-humans inhabited parts of India, China, Africa, as well as much of western central Asia. If Man inhabited central and east Africa, he may have seen the great volcanoes of that region. Java and other islands of Indonesia are crowded with volcanoes; but Java ape-man (*Pithecanthropus*) is very ancient indeed, taking us back at least a million years, and there is no proof that Man (*Homo sapiens*) was to be found there even 5000 years ago.

Other volcanic regions, such as the Aleutian Islands, Alaska, and Ecuador and Peru, were probably uninhabited 20,000 years ago; but true Man appears to have entered North America from Asia via the Behring Straits in middle Pleistocene times, although the date of Folsom Man is still uncertain.

Now, civilization can only arise where Man exists. If higher civilizations developed outside the belt mentioned in Chapter II one would expect to find some traces of them; but it is likely that many times uncivilized Man came in from outside and conquered the tribes living on the fringes of the fertile belt, taking their lands. What does seem certain is that Man grew up inside this belt, began to build civilization there, in a region stretching from the Caspian westwards to the Mediterranean (where volcanoes are numerous and widespread), eastwards to the Indus, and north-eastwards towards Central Asia.

Most volcanic explosions are accompanied by an outpouring of molten rock or lava, which boils red-hot over the lip of the crater or bursts out from the side and flows down the cone. It is somewhat viscous, so that it flows rather like molten metal mixed with slag, congealing into a cindery or ropey mass as it cools. Owing to its heat radiating into space, the surface cools and solidifies rapidly, but the interior, protected by the hardened crust, retains its heat for a long time – often for years – because rock is a bad conductor of heat. Such a lava stream, reinforced from time to time by fresh streams, may flow for miles down the flanks of the mountain, filling the valleys below, and everything capable of burning which it touches will burst into flame. Rivers of red-hot lava have been seen to set fire to woods, fields, houses and other combustible material, to melt snow, overwhelm villages, boil lakes, roast animals alive, and finally to reach the sea, sending up enormous clouds of steam. Naturally, great destruction is done, not only directly, but indirectly, by setting fire to forests. Nor would it be difficult to snatch a brand from the burning, on the edge of the fire, well away from the hot lava, and make off with it. This may have been done many times, in divers regions.



A fire-saw (wood).

That, or something very like it, seems to me to be what must have happened when Man first appeared in the Middle East. He stole fire from the slope of the 'burning mountain' where, thousands of years later, the god Atlas, who carried the world on his back, was believed to dwell; and other gods and daemons also, not at all well-disposed towards Man.

All this is pure conjecture. But it is reasonable too! The Greek legends and myths of 4000 years ago were certainly ancient when they were told in Greece. Whence were they derived, these stories of the man Prometheus stealing fire from heaven? Surely they were founded on fact; they recorded something that actually happened and was idealized for religious purposes, and fixed by repetition.

Be that as it may, Greek peasants carried fire about in a stalk of giant fennel down to the nineteenth century, as Prometheus is said by Aeschylus to have stolen it from heaven 'with a tube to cover his theft'. Nor is it surprising that for many centuries a sacred fire ever burned in the temple day and night. When Man first fled fearfully from the creeping river of molten rock, holding in his hand, perhaps, a burning stick snatched from the edge of the fire, the tribe must have regarded it with some awe. It needed no advocacy to make them regard it as the property of some mysterious power – the gods of a later age. Also, that was the safest way to ensure its preservation. On no account must it be allowed to go out, for it was a gift which would never be vouchsafed again – or a theft which could never be repeated. Man watching, red-eyed with awe, the streams of hot lava rolling with dreadful din down the mountainside, while forest and grass in its path withered and burst into flame, snatched fire daringly and bore it in triumph to his cave. Perhaps the wind blew the fire in his face, and he covered the flame. If this brand went out, fire might be lost to him for ever . . . Even ape-man may have done as much, half a million years ago.

There is no particular reason why the gods should be associated with fire any more than with earth or air or water. Amongst the animist hill tribes of Burma and Assam, the spirits *do* dwell in trees, rivers, mountains and rocks. But to early Man a volcano, *a burning mountain*, was the throne of the gods, no less; and who can steal from the gods with impunity? Not till long after this significant event, as we conjecture, did Man learn how to *make* fire at need.

CHAPTER V

THE DISCOVERY OF FIRE–II

IT was insisted on in the last chapter that a distinction must be drawn between the possession of fire and the means to conjure it at will out of the coldness of the Earth. Natural fire, it was pointed out, is a rare event. By some means, possibly a million years ago, ape-man somewhere had got hold of fire – how, we do not know; but, looking round the world at the known sources of natural fire, we were able to make a shrewd guess. There is little reason to think that *all* ape-men, who even a million years ago must have been widely spread over the Old World, possessed fire; nor is the evidence that even *some* did incontrovertible. But we can accept it as fact that fire was being used by primitive Man one or two hundred thousand years ago, during the time when the northern hemisphere was still in the grip of the Great Ice Age.

But that there is a clear distinction between the possession of fire and the making of it can hardly be questioned, when we remember that down to almost the end of the nineteenth century there were still a few tribes left in the world who did not know how to *make* fire. The Andaman Islanders, for example, and some of the coast tribes of New Guinea, *possessed* fire, and of course took great pains to preserve it; but make it they could not. However, it is possible that they or their ancestors may have forgotten, or lost, the secret. One can hardly suppose that these tribes have inhabited their present abode for thousands of years. They may have split off from a more cultured race, and deteriorated in their present surroundings. Such things have obviously happened many times. It is thus that the Earth has come to be populated.

Most, if not all, of the higher animals know that fire exists; at least, they recognize it and become ill at ease when they see it or smell it. Man or ape-man, not more backward, must have been aware of fire long before he learnt how to handle, and at length, how to tame it. In the beginning, primitive Man, like any other animal, was afraid of it. But as soon as he began to domesticate himself, he realized that fire, when kept within bounds, is comforting. Domesticated animals, as we know from the behaviour of dogs and cats, find comfort in front of the fire. On the other hand, when trapped with no obvious means of escape, all animals, whether domesticated or wild, go mad with terror.

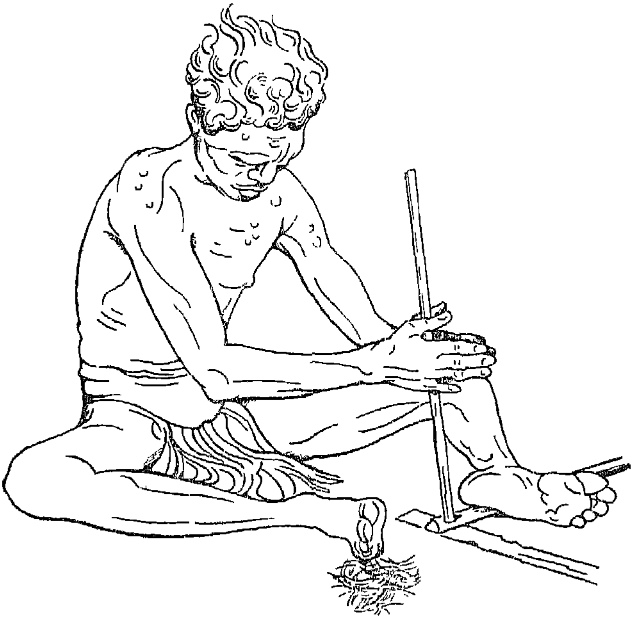
But how deep is the gulf between knowing fire and making it is well illustrated by a story told by Major Lewis Hastings in his robust book *Dragons are Extra*. A man travelling on safari in the Congo bush country frequently noticed neat little piles of sticks, such as a man makes when he wants to light a fire. As there seemed to be few inhabitants he asked his guides why they had laid so many fires and had never lit them. His guide told him that the sticks had not been laid by men, but by chimpanzees, in imitation of men's actions. So far so good. After that it seems the chimpanzees sat down by their piles of sticks waiting hopefully for fire to appear; and when it came not, they went off and laid another fire, or studied another man in the hope of seeing exactly what he did, and copying his actions once more; but as always, something essential was missing.

I remember once, during the hot weather in Burma, standing on the edge of a savannah fire, where the grass and scrub were being burnt to promote the growth of good pasture when the rains came. The fire, pushed by a faint breeze, crept slowly forward, the dry grass burning swiftly and lightly, the bushes going up suddenly in a burst of flame, while at intervals bamboos exploded like musketry. Immediately in front of the advancing fire line crept, crawled, flew and jumped an army of refugee insects, beetles, flies, bugs and notably large grasshoppers, suddenly and frighteningly disturbed. That they fled in panic I easily inferred from the fact that many of them, including large flying species of grasshopper, jumped straight into a creek which lay between them and safety, and had scarcely alighted on the water when they were snapped up by a number of fish which had gathered round and were lying in wait just below the surface! Man, too, had to learn this lesson of fire.

Early Man would rarely draw a logical inference from what he observed, and then only by chance. Never would he formulate a universal law. He did not understand the relationship between cause and effect. Thus it is quite likely that the discovery of how to make fire was often accidental. Nor is it possible to imagine how Man could ever have arrived at the final result – fire – by stages. Whatever process he used, either he made fire or he did not; there is no half-way house. That there is no smoke without fire was never truer than in this connection.

On the other hand, it is possible, even likely, that he made it intermittently; that sometimes his action, whether deliberate or not, resulted in fire, and sometimes it did not. For he could not have understood the problem. Most of us as children have seen certain results follow our actions without knowing how we achieved them. Success, if desirable, naturally surprised us, because it was unexpected. Only by constant repetition do we come to associate cause with effect, and repeat the action at will.

Successive failures, or merely non-occurrence if no conscious effort were made, would only convince Man how miraculous was his rare success. One can dimly imagine his terrified amazement when as a result of his operations he held in his hand a piece of wood that smoked, that glowed red, that gave off sparks in the wind . . . combustion!



An Arnhem nomad (Australia) making fire by means of firesticks and tinder. As one stick rotates in a slot cut in another, friction starts a flame.

However that may be, backward Man today makes fire by one or other of three methods: (i) flint and steel; (ii) friction by means of a fire stick; (iii) percussion. The principle in each case is simple, namely, that friction, or the compression of a gas (which is also friction) produces heat, and that heat, in the presence of suitable tinder, can give rise to fire, that is, combustion. But simple as it seems to us, it was not simple to primitive Man. Nor is the actual practice easy. Try to make fire and see! Even the production of a spark with flint and steel requires a certain knack. Which, if any, of the three methods in use today was first used by early Man?

If we consider the difficulty we ourselves experience in making fire by the pop-gun method, and by simple friction, we shall probably plump for frictional heat as being more easily produced than effective heat by means of compressed air, and fire as more readily produced by flint and steel than by either of the other two methods, if only because we see an immediate spark. But how could Palaeolithic, or even Neolithic, Man (ignorant of metal) produce fire with flint and steel, or iron? Iron did not begin to replace stone till late in the Neolithic Age, say some time in the second millennium before Christ; at least in Europe. Was the first making of fire accidental, or the result of conscious effort?

Man had been chipping stone axes, hammers, augers, scrapers, for thousands of years, and it is not impossible that sparks had been struck from a lump of stone containing iron ore over and over again. Indeed, it is rather likely that they had. Chipping flints, therefore, unlike rubbing sticks together, was an act at once necessary and familiar to primitive Man, and was being performed frequently by thousands of people in all sorts of places everywhere, for millennia. The Fueguans used to make fire by striking together lumps of stone and pyrites.

It seems at least possible, then, that Man may have produced fire by striking sparks from metal, not only long before he made use of metals, but long before he produced it by any other means; and this he may have done in any part of Europe, Asia, Africa or North America where natural iron ores are found. But on the other hand, the making of fire may be much more recent. For thousands of years all fire in existence may have been a clone, so to speak, derived from a single original fire 'stolen from heaven'. If modern simple methods of making fire are derived from older methods, they are probably recent, almost historic.

Man is an imitative animal. In his early days imitation is his *only* method of learning. Unconsciously the child imitates its parents. Thus every child, apart from whatever potential it may inherit, starts life with a certain amount of knowledge derived from watching its parents. Later the adult acquires fresh knowledge by observing its environment. The discovery that Man could *make* fire must have followed on possession of it; and possession itself followed on his recognition of fire as a natural occurrence. As it was terrifying, it was classed with thunder and lightning as a symbol of wrath; and until he could overcome his fear of it, Man could make no use of fire. But after keeping it for thousands of years and having in the meantime become more ingenious, he turned his thoughts to making it – perhaps under the lash of necessity. Fires sometimes went out!

I stress the point that Man had become more ingenious, because we have already looked at nature to see whether she provides an example of the making of fire which he could imitate, and have discarded them all as too fanciful.

Without the two human traits – speech and the knowledge of fire – Man was scarcely better off than his earliest ape-like ancestors. He was *Homo ignoramus*. But the fact is that he had a brain and itching hands, and achieved for himself both the miracle of speech and the miracle of fire. These accomplishments certainly took a long time, by human standards, to develop. Between undoubted ape and undoubted Man lies an immense gap of years, nebulous years about which it is difficult to be sure of anything. And yet somewhere in the world ape-man was advancing towards manhood, and somewhere else he was being snuffed out and having to start all over again, so that the final picture is one of general advance, although this idea is only attained by joining together a lot of distant points. In no one place, by no one race, was the drama of ape to Man played to a finish.

We can, of course, for the purpose of our story cut the knot and start with Man possessing fire, as we started with him walking erect and endowed with the power of speech. This, indeed, would be the logical thing to do, for clearly it was not Man who discovered fire, but ape-man; and in order to discuss the origin of fire, we have had to go back from our professed starting point many thousands of years. In fact, we have been worse than illogical; we have been inconsistent, since it is probable that Man possessed fire before he could speak, and this purports to be a brief survey of human footsteps.

But by the time he could speak, being the possessor of fire, living in caves or huts, eating cooked meat, going about in bands to hunt game, wearing animal skins, keeping herds and perhaps cultivating the soil in a small way, using tools, and possibly the simplest machine also, our hero is not just Man: he is Man well on the way to becoming civilized.

But while little is known about the evolution of speech, and too much can be conjectured to make it a suitable topic for discussion in a short essay, the same can hardly be said about the origin of fire. To shirk discussion here would not only deprive us of a most fruitful subject for speculation, about which enough is probably known to keep us within the bounds of sense; it would also be timid.

Our real starting point is true Man who can talk – if only thickly – and who can strike fire, who we may believe made his appearance in the Old World some 25,000 years ago, before the ice had altogether retreated from the central European plain; Man almost on the threshold of civilization. But again I must emphasize the profound difference between the discovery of fire and the invention of means to make it. In order to understand how he learnt the latter art, which is probably not more than 15,000 or 20,000 years old at most, it was necessary to discuss fire in general terms; and that, indeed, took us back into the dim past to a time when ape-man first became the possessor of fire.

In the last chapter it was suggested that ape-man saw fires started by red-hot lava from an active volcano, and possibly by lightning. Thus he may have obtained fire for himself. But for the purpose of *making* fire what good would that do him? He could not imitate nature there! Now we want to know how he learnt to make fire for himself.

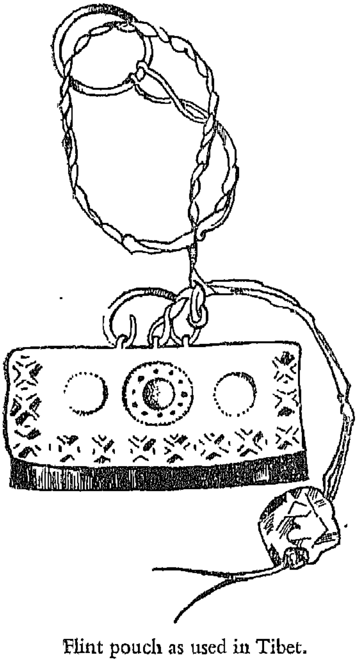
But before we pass on to the problem of how he learnt to call up fire out of the void, let us just glance at a few other theories, more picturesque than probable, put forward to account for the possible genesis of fire in nature, which have gained a certain amount of credence from the uncritical.

One of them, not the most far-fetched, is the forest friction theory, invoked, we may suppose, to account for otherwise unaccountable forest fires. It has been seriously suggested that such fires have been started by the friction of two boughs rubbing together. That boughs often do rub together is undeniable; so often, in fact, that if it were the source of heat it is thought to be, forest fires might well be more common than they actually are. Ideal conditions should be obtained when dry bamboos rub together. In the deciduous forests of Burma and Assam I have not infrequently seen this happening in the hot weather at the time when the hill tribes burn the forest to make clearings for their crops; two tall bamboos, grazing each other as they sway gracefully to and fro. Yet when we consider how difficult it is to produce fire by the friction of wood against wood, how rapid and sustained must be the motion, the unlikelihood of those conditions being fulfilled in nature is obvious. Two dry bamboos may rub slowly and intermittently, being dependent on the fickle wind; but no perceptible heat is engendered, and such as it is. it is dissipated immediately. And where is the tinder, so vital to the making of fire by this method – or by any similar method? Fire never could, I believe, be raised by such leisurely means. The attractiveness of the idea lies in the fact that, if true, it not only produced fire, but even showed Man how to make it for himself! True, there is respectable authority for the occurrence of forest fires in South India caused by this means in a high wind, though so far as I know it has never been *seen* to happen. I personally, after some experience of bamboo forests, regard it as incredible. But even if true, it proves nothing to our purpose, unless Man lived in such forests.

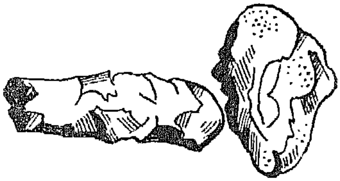
Again, it has been ingeniously suggested that drops of water, acting as lenses, have so concentrated the sun's rays as to cause fire. Dew drops sparkling on leaves and grass are a familiar sight, and we know that it is easy to produce fire by means of a burning glass, using the right kind of tinder. It is sad to have to demolish so picturesque an idea as chains of dew drops starting a chain of little fires at sunrise. All we need point out, however, is that if the grass is drenched with dew no number of dew drops can set fire to it. Moreover, dew occurs in the early morning and evening, when the sun is low down in the sky and least effective. True, it can rain in the middle of the day, with sunshine to follow. But the same unsuitable conditions apply – wet grass and lack of tinder.

Nor from the possible causes of natural fire must we exclude bacterial processes, as in damp haystacks, cotton bales, and so on. But it is difficult, if not impossible, to see how primitive Man could have had any knowledge of such spontaneous combustion, or could have benefited by it if he had. For spontaneous combustion comes rather within the scope of man-made events, and is comparatively rare at that.

Finally, we may glance at phosphorescence, which is common in nature, though the most notable thing about animal and vegetable phosphorescence – living light – is the production of light without heat. Primitive Man, of course, would not ponder that problem. He would remark that the sun gave out light and heat, but that the moon gave light without heat. It is impossible to imagine him drawing any inference whatever from such phosphorescence as he came across, especially as one of the commonest sources would be along the sea shore, sparkling amidst the waves. Glow-worms, fire-flies, rotten wood covered with phosphorescent fungus, do not suggest fire; in fact, it requires an effort of the imagination to connect them. They are simply cold light, and hence mysterious. As for the other theories mentioned – dew drops acting as burning glasses, and, one might add, will-o'-the-wisp or the spontaneous combus-



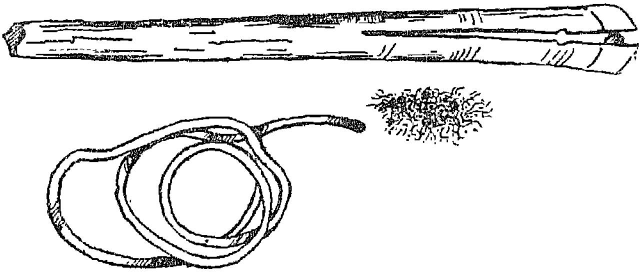
Flint pouch as used in Tibet.



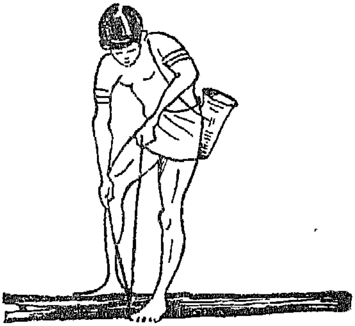
Flint and pyrite for striking fire.

tion of marsh gas – the first, we may agree, never happens, and the second is inimitable.

Turning to the three primitive methods of making fire which survive to this day, a few words may be said about each. Flint and steel, obsolete in western Europe and elsewhere these two hundred years, is still the ordinary way of striking a light in Tibet and throughout Central Asia, as well as in many other parts of the world. In Tibet the steel, curved like the edge of a battle-axe, though more gently, is attached to a leather purse consisting of a pocket covered by a flap. In the pocket are kept small pieces of flint and tinder. For the purpose of making a spark, a flint chip and tinder are held together between the index finger and thumb of the left hand, and the flint



Fire-saw with thong and tinder (Assam).



A Naga hill-man making fire with a thong.

struck sharply downwards with the steel. It requires some knack to direct a spark on to the tinder. More primitive flint and iron are used by some of the hill tribes of Burma.

The wood friction method has many variations, one of the simplest and most effective being that used by some hill tribes, including the Naga tribes of Assam. A piece of soft wood is split, and wedged slightly open by means of a pebble. A two-foot thong of bamboo is passed through the slit, the ends being held in the hands. The stick is laid on the ground and held steady with the foot. Tinder is packed under the stick and within the slit, and the thong drawn rapidly up and down. At the end of half a minute, sufficient heat is produced to light the tinder.

The percussion, or pop-gun, method is less common, but may still be seen amongst some of the tribes of North Burma. It depends on the fact that air suddenly compressed, as by a sharp blow on the end of a piston, raises the temperature high enough to ignite tinder appropriately placed.

What are the chief advantages in the possession of fire? All of us, at one time or another, have known the discomfort of *not* possessing it, in a very small way, as during a gas strike, coal strike, 'economy fuel cuts', or for some other reason; but though we personally may have been temporarily deprived of fire, the community as a whole was not, otherwise life would have been intolerable. It is for that reason that we find it difficult to picture a world when fire had no existence, at least so far as Man was concerned.

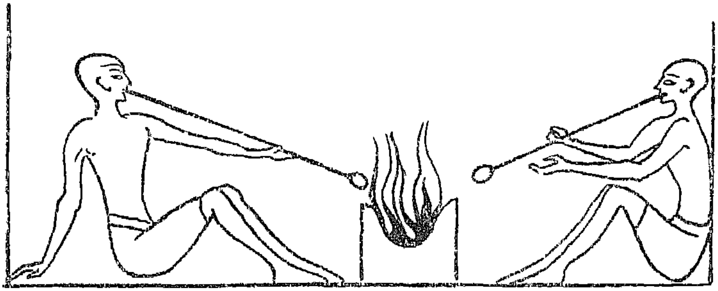
The principal advantages seem to be:

(i) Caves became habitable. Fire kept off wild animals, warmed and lit the cave. In fact, Man could camp anywhere where there was firewood and be reasonably safe from attack by wild beasts so long as he kept the fire alive.

(ii) Man, for the first time, could cook his food – a tremendous advance. Not only did it make his food more digestible and palatable, it extended its range. We have already referred to the anatomical change in human appearance, and discussed what part eating cooked food played in it.

(iii) Man could advance into regions with a climate colder than any he had withstood previously.

(iv) He was no longer compelled to migrate in winter.



Glass blowers, after a painting from an Egyptian tomb.

(v) He could signal from hill to hill across a valley; for fire means also *light*.

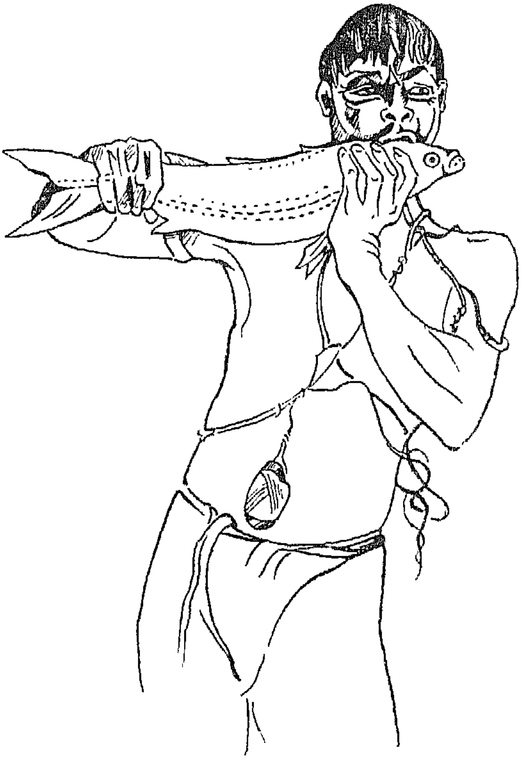
(vi) Eventually he learnt to smelt ores, hammer iron, and do many other things, such as glass-blowing, which are impossible without fire. The arts were born.

Thus Man's whole style of life, his economy, was revolutionized. Everything was changed; and in the end Man himself changed also.

This command of fire – what wonderful power it gave to Man the food-gatherer! Long before the domestication of plants had begun, Man was human. Think of the trouble and heart-breaking search it would save! The animals have left the valley – no man knows why. The family goes forth to seek food. They search all day, but luck is against them; they find none, or only the most meagre fare, and return hungry. Next day they set out again in a new direction, still in vain. They return once more. Now they are clamorously hungry. Already the children are beginning to fail. Men and women are tired, famished, desperate. At last, when hope is waning, they find what they seek – food plants, grain! Nor was it so far from their home after all, only difficult to discover. They mark the place and return next year. They destroy useless plants to increase the growth of the food plant. (Thus do the Mishmi tribe in the frontier mountains of Assam make small clearings in the forest to encourage the growth of a wild plant, *Coptis teeta*, the root of which is used as a medicine.) And now to apply fire! Man could parch the grain – and how much better it tasted that way! How much more nourishing!

So improvements, inventions, discoveries, went on slowly side by side. Their wide diffusion took ages. We must try to picture ancient Man in that bleak world when the ice sheet was retreating from northern Europe and Asia, leaving the land covered with stiff, hungry boulder clay, heavy and forbidding. Man had to work hard then to live. Food was his chief, almost his only need; food and warmth, and presently clothing and protection. We must picture him, too, thousands of years before the ice finally retreated in the northern hemisphere, living in cold, damp regions. We speak of primitive Man doing this and that. Looking down the long corridors of time, we have to generalize more and more, to speak of Man almost as an immutable law of nature, so imperceptibly does change occur. But in reality almost every tribe, every family, had a different experience and reacted differently, found a different environment, solved their problems each in their own way. On every hand Man was experimenting, striving, bound by the social instinct far less than modern man. Civilization was still a long way off.

So he plodded on through the centuries, over the strange world of 50,000 years ago, and after all his wanderings he began, slowly at first, to settle down. He became a gardener, a farmer, a husbandman, as well as a herdsman. Presently he became an artificer and craftsman. The control of fire



Some South-Sea Islanders, after biting a netted fish on the back of the neck, immediately eat it raw.

ushered in the age of metal, first as a substitute for stone, later in the arts, and in war.

But as I have observed, so wide is the gap between the first possible possession of fire and the first probable invention of how to make it at will, that it is impossible to say when it was first used for purposes other than cooking, warming and keeping at bay wild animals.

I have already referred to the advantages of cooked food over food eaten raw; they are far-reaching and profound. Many things which are indigestible while raw become nutritious when cooked. We need not consider certain modern problems, such as polluted water, for we may be fairly sure that primitive Man had ample supplies of good drinking water free from the germs of water-borne diseases. That was not one of his troubles. But cellulose is indigestible by humans, and it is only when the starch-containing cells of foods like the potato are burst by heat, setting free the starch, that they become edible. Beech nuts, acorns and roots probably formed a large part of the diet of early Man.

It may be that to primitive Man the most valuable use of fire was in protecting him against savage beasts, great numbers of which roamed over Europe, Asia and Africa within historic times, and still more in prehistoric times. For the first time he was provided with a weapon which no wild animal could either match or encounter without fear. Not all the patience and cunning of the sabre-toothed tiger, nor the royal fury of the lion, would avail against fire. An impregnable barrier had been erected between Man and beast; from this moment they were fated to diverge further and further apart. The only link between them in future would be the domestic herd.

Then, too, he would be reasonably comfortable in his cave. In fact, it is difficult to imagine cave-men without fire.

Caves must for long have been the lair of beasts, nor would it be easy for Man to drive them out. Once he had dispossessed them, they would be loath to challenge his tenancy across the fire on the threshold. In the arts fire was invaluable for opening up new industries, offering him metal in place of stone. We may say, then, with some confidence that for the last 10,000 years or more Man has been rapidly widening the gap, already considerable, between himself and the rest of creation.

I have dwelt at some length on this theme because of its deep significance. Without fire Man would have got nowhere. He owes the fact of his manhood as much to this earliest discovery of all as to his power of speech. Let us now turn to Neolithic Man, and say something of his contribution to civilization.

CHAPTER VI

THE DOMESTICATION OF PLANTS

NO discovery ever made, or ever likely to be made, can rival in dramatic quality the discovery of fire. It settled once and for all Man's dominion over the Earth. It made ape-man Man; it made civilization possible; and the making of fire was the one major invention which penetrated to every corner of the inhabited world before the next step was taken anywhere, though it may have originated in and spread from more than one centre.

After the discovery of fire, tens of thousands of years rolled by before any advance was made. Even after the invention of means to make fire, a long time passed before anything more was done. Man was already quite definitely Man; *Homo*, though not yet *sapiens*. Certainly not everywhere *sapiens*. *Homo sapiens* may have been one of half a dozen *Homos*, destined shortly to become the dominant one, but even so varying considerably over different parts of his ever-increasing range.

By the time Man cooked his food over a fire and warmed himself round its welcome blaze, he went about in families, and families perhaps banded themselves together into clans or tribes. That tribes can originate from powerful families is obvious – how else could they originate? – and we know that the powerful Lushai tribe on the Assam frontier did so originate about two centuries ago, carrying all before them. But even in possession of fire, it is questionable whether Man would have become thoroughly civilized had it not been for one other momentous step, which also spread over the whole inhabited world at a very early period; or at least its results did.

For Man now made another stride forward; he began to tame animals and to domesticate plants. It was no sudden leap in the dark, but part of a deliberate march towards the light. It could not have happened all at once; the domestication of an animal such as the wolf must have taken a long time. Nor could it have happened just anywhere, nor everywhere. The only place where it *could* have happened would be in that land over which Man himself wandered where the the animal to be domesticated was found wild. This is not necessarily the same place as where it is found wild today – if, indeed, it occurs wild at all. We do not always know for certain exactly what wild species our modern domestic animals represent – if there *is* a corresponding wild species.

During the last 10,000 years there have been considerable changes of climate in the northern hemisphere, and far greater changes during the last quarter million years. Change of climate implies change of vegetation, with consequent migration (and sometimes extinction) of animal life. Within the last 25,000 or 50,000 years, at least two distinct faunas have alternated in central Europe, owing to the fluctuation of the Pleistocene glaciation – an Arctic fauna such as exists in the far north today, and a warm temperate, such as still inhabits southern Europe, the Near East and North Africa. Very few mammals have become altogether extinct, though many have left Europe.

The earliest domestication of animals and plants must have begun a long time ago, but we cannot put any exact date to its beginning. In Mesopotamia both domestic cattle and corn were known so far back as 8000 B.C., and it is thought by some archaeologists that cultivation goes back beyond 10,000 B.C., though hardly to 12,000 B.C. At any rate, the earliest civilizations of which we have contemporary written history were peasant civilizations; and the cultivation of fields or gardens does not spring up overnight as a going concern. Unlike fire, it comes step by step.

A great deal of research has been devoted to the origin of our cultivated plants and domestic animals, and we know a good deal more about the subject today than we did at the beginning of the century. Yet it cannot be said that we are much nearer a solution of those insistent questions: *where?* and *how?* *Where* did Man fence the first fields? *How* did he domesticate the first animals?

People sometimes ask: which came first, the domestication of animals, or of plants? Or did they both come together? A clue to the past may often be found in the present. That children are more enthralled by animals than by plants is proved by the larger number of children to be found at the Regent's Park Zoo, in London, than at Kew Gardens, in spite of the advantages of the latter as a picnic resort. The cynical might say that children visit Kew Gardens rather for fun and games than to look at plants! Savages are not unlike children, and it is a fair inference that they too are more interested in animals than in plants. Hence they would be more likely to take notice of them first, and so (we may suppose) experiment with them before turning their attention to plants. But much would depend upon circumstances; and if early Man lived chiefly on roots and berries, as seems probable, he may well have begun by trying to cultivate plants, which are more inert.

As the centuries rolled on, the climate of Europe gradually changed, though faster, perhaps, than it has done during the last millennium. The ice slowly retreated in the Alps, and the belt of country well-watered by the westerly winds from the Atlantic shifted northwards again. Forests of beech, birch and pine replaced the steppe vegetation as the glaciers shrank; other deciduous trees, such as alder, oak, elm, hazel and lime sprang up, and with the change of vegetation came a change in the animal world. South of the Alps, the Mediterranean basin was becoming arid, and northern Africa was turning from prairie into desert. There must, one supposes, have been great tribal migrations during these changeful years, especially between the eighth and fifth millennia before Christ. It was during this critical time, surely, that Palaeolithic Man in Europe, and Neolithic Man in Africa or Asia, first turned their attention seriously to the domestication of animals and plants.

Man was originally a food-gatherer – he wandered about incessantly and collected food where he found it, plant or animal. To be a food-gatherer is to be nomadic; there are nomadic food-gathering tribes on the outskirts of the habitable world today. In some years particular plants and animals are locally scarce or locally plentiful. Food-gatherers searching their accustomed grounds one year, and finding little or nothing, might be faced with starvation unless they wandered further afield.

But this was to plunge into the unknown, a fearful undertaking. It might bring them into conflict with another tribe, on whose lands they were trespassing; or it might bring them into a richer, more desirable, unoccupied land. Anyway, if they were starving, it was a risk the bolder spirits among them would take. Perhaps they stayed in the new country; perhaps they returned to the old hunting grounds. Meanwhile it may have occurred to them that, if they sowed some of the fruits and grass seeds which they habitually ate near their caves, not only would it save them the trouble of going to look for the plants but in famine years there would be an assured supply on their doorstep. So at least they might have reasoned. Therefore they set to work to increase the food supply. 'Grow more food,' they said, 'and save trouble!'

Famine conditions may have suggested this way out, but it is just as likely that even in normal seasons they found large stocks of their favourite grain some distance away from their home ground, whether cave or no, which, for other reasons, such as water supply, they did not wish to abandon. Again, it would be good policy to save some of the seed and grow the plant nearer home, thus making such long journeys unnecessary. It is, indeed, not difficult to suggest reasons why Man might have started gardening – it did not for a long time reach the status of agriculture – or how it may have begun. Seeds may have been thrown down accidentally, or thrown away on purpose, near the tribal home; or efforts at gardening may have been made in a district where the desired plant was fairly abundant; or food offerings to the spirits may have germinated. We are not likely to know for certain what happened, but any or all of the above causes may have operated. Again, there is no reason why gardening should not have started independently in several, or even in many, places. One may note in passing that in the mountains of India's north-east frontier the hill tribes invariably interplant their crops with vegetables; only wet rice is grown by itself.

So we find Man, roughly clad, experimenting with plants which he is presently to domesticate; wandering about in bands following the great herds of game; experimenting also in the domestication of wild animals; seeking food and clothing, shelter, warmth and protection at night.

In what parts of the world was he wandering thus? Certainly along the river valleys throughout Europe, except in the extreme north – Rhine, Danube, Seine, Somme; south-western Asia, North Africa, parts of India perhaps, and in the wide valleys of north-eastern China; in fact, over a large tract of the semi-desert belt which stretches diagonally across the Old World from the Atlantic to the Pacific. There must, too, have been human outliers in Africa, while wandering Man may already have reached the Pacific coast of North America.

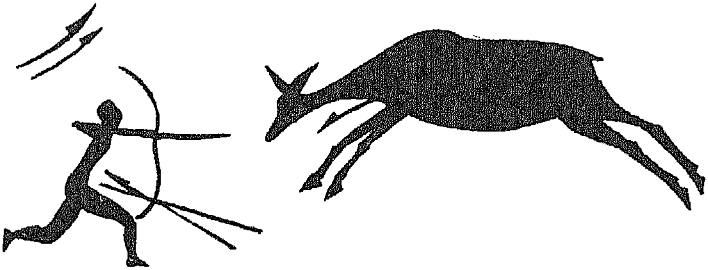
For civilization could only have been invented in dry, semi-arid lands, never in regions of heavy rainfall, a steamy atmosphere, or evergreen jungle. The great tropical river deltas, such as the Ganges and the Irrawaddy, and the moist foothills of great mountain ranges like the Himalayas, must have been occupied by Man long after the deltas of the Nile, the Shatt-el-Arab and other rivers of the arid belt, or the arid hills of Persia and Afghanistan.

Apart from the two outstanding achievements mentioned, that is to say, the discovery of fire and the domestication of animals and plants, Man was not yet – say about 7000 B.C. – noticeably more civilized than he had been for the last ten thousand years. Nevertheless he may have been more civilized than some of the most degenerate tribes of today who inhabit the jungles; the Solomon Islander, the Salon of the Mergui Archipelago, or the Sakai of Malaya. Already he had clearly marked out a future for himself.

It is easier to conjecture both how and why Man domesticated the first food plants than the first animals. He was, as we have seen, a food-gatherer. Hunting for him was no sport, it was deadly serious, though even so he may have found satisfaction in it, even enjoyed it. He hunted game for food and clothing, possibly also for blood sacrifice, though human sacrifice was a more sophisticated idea. He may have lived partly on meat, when he could get it, for 10,000 or 12,000 years ago there was much steppe land in Europe and western Asia. One would have had to cross the Mediterranean to find forest; but his diet, one may suppose, was largely vegetarian.

On the other hand, it seems likely that it is just on those cold, wide pastures that he would find least vegetable food for his own needs. Cereals there might be, but most of the edible fruits are more characteristic of warmer forest-clad lands. The food-gatherer, in fact, did not have an easy time; to find all he needed he had to cover much ground. Perhaps the women gathered fruits and seeds while the men hunted.

All the more likely would it be to occur to some of them that they might save themselves long journeys by gardening at home. Moreover, where grazing animals are plentiful, carnivores which prey on them are also plentiful, and so before the invention of firearms, before even the use of metal, with nothing better than sticks and stones for weapons, Man had to be wary. Long journeys, except in large bands, might be fraught with danger, especially at river fords, on passes, in defiles, near saltlicks, and so forth. Women, though no doubt Amazons, or, in the defence of their young, tigresses, had to look after small children; and it would be a risky thing to let parties of women and babies wander far without male protection. In many regions, with the weapons at his command, Man found it easier to discover edible plants than to outwit animals.



Stone Age cave painting (eastern Spain).

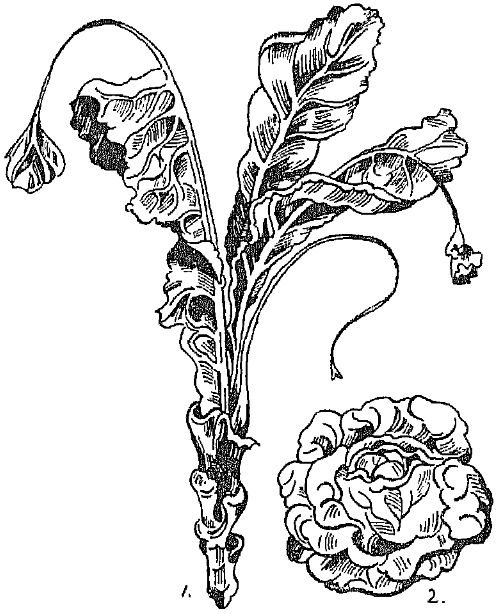
Thus another compelling reason for establishing the home near the food supply, or alternatively the food supply – that is, the plant food supply – near the home, suggests itself. It would, of course, be only reasonable to fix one's abode in a good game country and, even more important, near a good water supply. But that would not be the only consideration in choosing a home. Many an open grassy plain, desirable for its abundance of game, might, if it offered no shelter, have unwillingly to be forgone.

It is not, of course, suggested that Palaeolithic Man was static, that he lived in tribal villages, or even in huts or caves, during these early ages. Man was for millennia nomadic; and it was his attempts at gardening and at the domestication of animals which gradually tied him down to the land.

But even in his most nomadic days, he could not have been always on the move. There must have been times, seasons, when he was more or less static. The belief that Man has passed through three distinct phases – as hunter, pastoralist and agriculturalist – is certainly false. Different states of culture have always overlapped in different regions, sometimes by many centuries, as they do today. The inhabited world never has comprised only hunters or only pastoralists or only industrialists; for human occupations are mainly dependent on environment and the existing level of culture. Man in the beginning was a food-gatherer, and from very early times a gardener. Even so, as a nomad, there were times when he stayed put and could take care of animals, and times when it nevertheless paid him to go a-wandering, or even to change his abode.

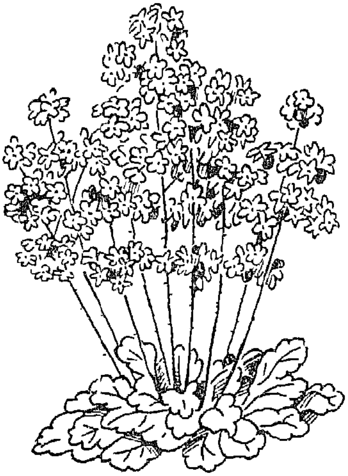
Under such uncertain conditions one may believe that in some places he began experiments in gardening, even before he tried to domesticate animals; but we are not likely ever to be certain of this. It may be that over different stretches of the vast area Man already occupied, if thinly, both gardening and domestic animals originated independently at many points; and that in one place gardening, in another the domestication of animals, came first.

Some of our domesticated plants have changed their appearance, so much so that they no longer resemble their wild forebears. Many of the changes have taken place under domestication, and therefore it is useless to look for a wild forebear like itself; it never had one like itself. Today we might go out into the country and dig up a wild plant and transfer it to our garden, where it will receive a good deal of unaccustomed attention. In its new setting it might or



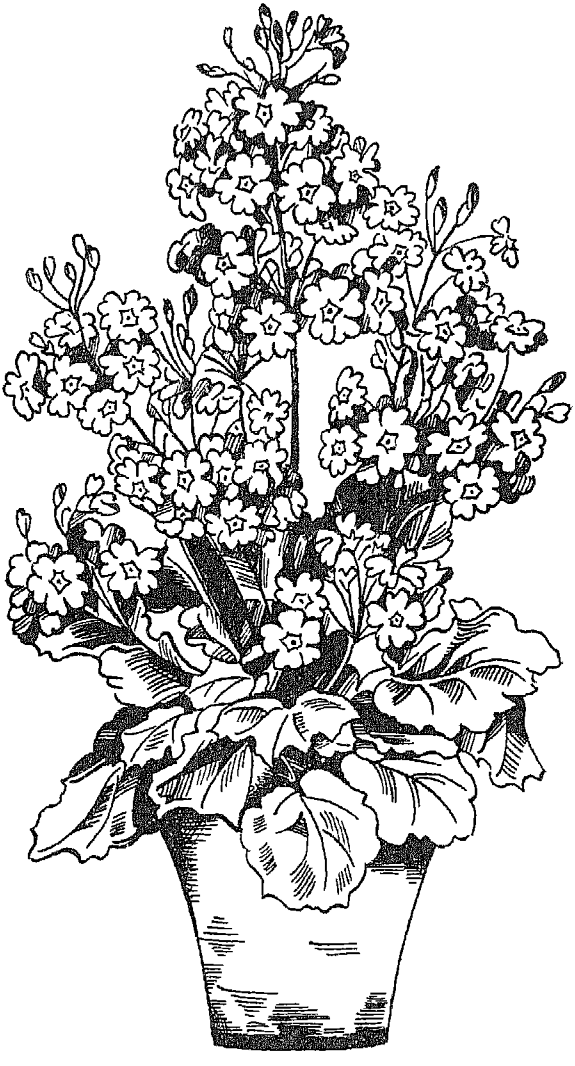
(1) Wild cabbage, (2) Domesticated cabbage.

might not show to advantage amongst cultivated plants; but at all events it will probably remain a wild plant for the rest of our – and its own – natural life. It might not change its appearance for very many years, if ever. But now we are speaking in terms of decades, whereas our cultivated food plants have been cultivated for centuries and for millennia.



Primula malacoides.
Wild species of western China.

But is it strictly true that the wild plant will not change its appearance? If we raise thousands of plants, and select from them carefully for a given end, the answer may be rather different. At the end of ten or twenty years we may hardly know it for the same species. What about *Primula malacoides*, for example? Introduced into Europe in the first decade of the present century, from western China, it has been changed out of all recognition in the space of a quarter of a century. Those who buy, today, a pot plant of *Primula malacoides* in Covent Garden market in London would hardly suspect it to be the frail fairy plant so common in the rice fields of Yunnan, 'improved'. The same applies, no doubt, to animals – white rabbits, for instance, or valsing mice. But with most plants and animals probably no appreciable difference is noticeable even in several human generations. Some animals can be tamed fairly quickly; but there is a wide gap between a tame animal and a domestic one.



Primula malacoides. Domesticated species.

There is probably less mystery about the origin of the many cultivated plants than about the origin of the few domesticated animals. The researches of de Candolle in the nineteenth century established the original home and approximate age of most of our cultivated plants; few baffled him. In the present century the Russian botanist Vaviloff has re-examined this problem. He has challenged some of de Candolle's conclusions and cleared up some of the mysteries, though there is still doubt concerning the origin of several cereals, notably some of the varieties, and species, of wheat, no wild plants of which have ever been found. The origin of rice, too, is uncertain although it must have been somewhere in south-east Asia. With the botanist E. J. H. Corner I once found wild rice growing on the mainland of Johore State, opposite the island of Singapore. It looked like a rather skimpy edition of the cultivated plant; at least, it was recognizably rice.

With animals it is different. We find pictures of animals, both domesticated and wild, drawn on the walls of caves by Stone Age Man in Europe and Africa, but never a hint as to *how* this domestication was brought about. It is therefore largely a matter for conjecture.

He would be a bold man who would say that in the next 500 years no new animals will be domesticated, still more, no new plants. But what good purpose would the former be likely to serve in a world already critically short of fodder?

CHAPTER VII

THE DOMESTICATION OF ANIMALS

IT is believed that the first animal ever domesticated anywhere was the dog, derived in some way unknown to us from the wolf, and not, as one might naturally suppose, from the fox, jackal or wild dog; and that all the dogs in the world today are derived from one, or at most two, species or varieties. Neolithic Man, and Palaeolithic Man too, lived largely by hunting, and food was a prime necessity. In cunning and ingenuity Man was already far superior to any beast – he must have been since he was able to domesticate himself; but in strength, in fleetness of foot, and in power of scent, he was immeasurably inferior. His most pressing need, after food, was no doubt protection from his enemies, some of which were also his rivals, seeking the same food. A protector was needed, and the animal which became Man's faithful protector was the savage wolf. Nor must we forget that Man may have eaten the wolf, or dog. There are tribes on the Burma frontier today who still regard the dog as a delicacy; the Maru tribe carries on a regular trade in dogs for food. The first cattle were probably domesticated about the same time as, or a little later than, the dog. We do not know the date; but we do know from drawings of dogs in caves, the date of whose tenancy is approximately known, that it was some time before 5000 B.C. Dogs are not the only hunting animals whose skill was bent to Man's use; but others, such as the falcon, cormorant and ferret appeared much later. Even the cheetah, which has long been known, came ages after the dog.

A sense of ownership was also growing up, and it must soon have become necessary to guard such property and rights as Man recognized. Private property forms the only stable basis of society. Here again the dog was becoming useful; and whereas cattle provided both food and clothing, they themselves were soon to need guarding. Most wild cattle, however, are far from helpless, and are able to stand up for themselves against anything except armed man.

If the first use of domestic animals was for hunting and for protection at night, and the second the provision of food and clothing direct, a later and no less important development was the substitution of animal muscle power for human muscle power, thereby giving Man rest and even leisure. Further, they did more work in a given time.

At first sight it seems very strange that so savage and dangerous a beast as the wolf should have been chosen to serve Man. Why not start the experiment with a more tractable, even a more gentle, creature like the sheep, or the goat, or even the ox – although most wild bovines are not so gentle either! But when we recollect that one of Man's most pressing needs was *protection*, it is no longer surprising. Naturally he chose a protector which *was* savage, and which might therefore be relied on to protect him. What gentle

Some tribes on the Burma frontier carry on a regular trade in dogs for food.

or timid creature would be of any help in the hurly-burly world of 8000 or 10,000 years ago! There was another advantage in choosing as guardian, first of himself and later of his cattle, a hunter; for Man himself was a hunter, though a less skilled one. A wolf might be able to pull down game, in country from which game was gradually disappearing, more easily than Man could; and it saved Man time and hard labour if his watch dogs, besides guarding the home, also hunted for him.

Had it not been for the discovery of fire and the domestication of the dog, Man might not have survived those critical centuries, in spite of his growing mental superiority. He could not always guard against his enemies day and night, and there may have been times when he would have starved to death but for his hunting dogs. When he settled down in the first encampments, he needed to set a guard over his flocks and herds, and even over his crops. We may be sure that he had no herds *before* he had trained dogs to guard them, and warn both them and himself of approaching enemies.

But even before he settled down, while he still wandered from pasture to pasture with his flocks, he needed a guard. The guardian dogs of Tibet are an essential part of every nomad encampment. Hence the likelihood that the domestication of cattle, sheep, and goats ran parallel with the domestication of dogs to take care of them; it is at least probable that with the beginnings of the settled life, with helpless herds and timid flocks, protection would have priority.

It is surprising that early Man should have domesticated almost all the animals which, it seems, are capable of being domesticated, or worth domesticating, so long ago. Apart from varieties, the number of domestic animals is very small, and the majority belong to the temperate zone. The only tropical mammals to be domesticated appear to have been the Indian elephant and the water buffalo. The cheetah, or hunting leopard, was probably never more than outwardly tamed, and this seems to be true of the African elephant also. A few tropical birds, such as the guinea fowl, Indian jungle fowl and peacock, have also been domesticated, more or less.

The origin of domestic oxen, now found in almost every country in the world, is more obscure; but Indian cattle were perhaps derived from one or other of the tropical bovines, or possibly from the European wild ox. The Indian water buffalo is descended almost unchanged from the wild buffalo. When the wild bovines – for example, the gaur (*Bibos gaurus*) – interbreed with domestic oxen, one gets hybrids such as the mithan, a semi-domesticated ox kept by the hill tribes of Assam and Burma.

The camel is rather a sub-tropical or warm temperate animal, peculiarly adapted for life in the desert; though the Central Asian two-humped camel, even better than its one-humped Arabian relative, can stand intense cold. So also can the yak. Amongst the last animals to be domesticated were the South American 'camels'. It seems that Man did not reach South America till quite late; a few thousand years ago.

No major animal has been domesticated since the birth of Christ, and no extinct domesticated animal is known. Few large animals have become totally extinct since Man appeared, though several birds, like the dodo, greak auk and moa (all, be it observed, flightless), have become extinct within historic times. The Irish elk and the sabre-toothed tiger may have been exterminated by Neolithic Man within the last 7000 years.

We cannot hope to get a complete picture of the domestication of animals, however, until archaeological research has told us more about early Man, where he lived, what the climate and vegetation were like, and what animals were his contemporaries. Where, for example, was the reindeer domesticated? It is at least unlikely that this took place in the far north. It seems much more probable that the reindeer was domesticated in central Europe, whither the Arctic fauna was driven during the Pleistocene Ice Age, and that when the ice finally retreated it went north again with its master.

There are many peculiar facts connected with Man and his animal auxiliaries. I have referred to the reindeer, one of the most useful animals known. Why should it be the only species of a large number of deer – whose meat is highly appreciated, whose skins are useful and whose horns are valued as medicine – to have been domesticated? India has many deer, but not one of them has even been tamed. Note, however, that the sambur is not mature for two or three years, while the pig is mature within a year. Hence, so far as reproduction and quick multiplication (and hence food) is concerned, the latter is the more valuable animal. Again, it is surprising that no monkeys, which might reasonably be expected to co-operate with Man, were ever domesticated.

The advantages gained by domesticating animals differed from those gained by domesticating plants. Both ensured a food supply; but whereas gardening tended to tie Man down to a particular locality, the great advantage of herds was that they travelled with Man into regions where game was scarce or absent. Food on the hoof obviously increased Man's radius of action enormously. It was in no wise calculated to anchor him or curb his restlessness and thirst for adventure. And yet, the combination of gardening and herding did help to put a brake on his incessant journeyings. More than eight thousand years ago he had certainly formed permanent settlements in the Middle East.

Man's first need is satisfaction of his appetites, while he seeks happiness, which means freedom from anxiety. He also desires ease and comfort. But those are more difficult to attain, because comfort is whatever you are thoroughly accustomed to, so that any increase of comfort (unless very gradual) is achieved against the grain. Man fears change and finds it embarrassing. One can be happy, and even comfortable, in a state of utter exhaustion. Perhaps the distaste we all feel for death is just that anxiety about any new situation; we are more accustomed to being alive.

Early Man, in his struggle for survival, must frequently have exhausted himself more than any modern athlete. He was probably all too often almost on the point of collapse in the chase – or while being chased! Nor was there much happiness in it. The endless search for food kept him ever weary. What escape could there be from expending prodigally his own energy? Well, were there not wild animals with muscles stronger, and therefore more tireless, than his own? If only *they* could be trained to help him! We who come in contact with domestic animals every day of our lives, and rarely see a wild animal (birds excepted) unless behind bars, cannot easily conceive a world in which *all* animals are wild animals. If we give the matter thought, however, we can perceive the enormous difference the domestication of the first few animals made in Man's economy.

(i) Being stronger, swifter and more patient than Man, animals can do work which Man by himself cannot do at all, or can do only at intervals, and with an effort.

(ii) They can be used for chores which Man *can* do, but which he would rather not do, thereby saving energy and irritation.

(iii) They can work longer hours than Man.

Fuzzy-haired Hadendoa of the Anglo-Egyptian Sudan load their children and chattels on camels.

(iv) They give food and clothing on the spot, thus saving much human energy and, so long as they are fed and cared for, ensuring a steady supply, and eventually a *surplus which can* be stored, or exchanged.

(v) They can travel with Man, thereby not only saving him the labour of hunting, but even carrying his loads, before being themselves turned into food.

These uses have, like other uses, survived into the present. There are, of course, fewer beasts of burden in Britain today than formerly, and the draught horse, almost driven off the streets by the petrol engine, is now being driven off the farm. The real wonder is that it should have survived in Britain at all.

However, if we want to see the beast of burden as it was in the beginning, we have only to look round the world and we shall find horses, donkeys, camels, llamas, yak and even sheep carrying loads on their backs heavier than a man could carry; elephants pushing and lifting and dragging tree trunks in Burma and Siam; bullocks lifting skins of water from wells in India, trampling out grain, turning sugar and oil presses, or grinding corn. In Japan, China and Tibet we shall even see men still being beasts of burden themselves, carrying immense loads for long distances over the trackless mountains, or pulling rickshas and pushing whole families seated in wheelbarrows through the teeming cities.

In the modern world, too, animals are used to perform other work, though only on a minor scale; thus we have carrier pigeons, and all the sporting animals used for racing or fighting, including dogs, horses, cocks, bulls and others. By the time Man had become civilized, a few animals, such as horses, elephants and, later, camels were being trained directly for use in war.

How Man picked on the plants and animals he did finally select for domestication can only be a matter of conjecture; but there is no good reason to suppose that he would act very differently from ourselves under similar conditions. He had been food-gathering for thousands of years; and though he did not write down his observations, there must have been a fixed tradition, a certain amount of common knowledge handed down from father to son concerning a number of animals and plants. Animals know what food they prefer, and where to find it; so why not Man! He can hardly have been watching and hunting animals, searching for and collecting seeds and fruits, for generations without learning a good deal about them. And of course the first thing he learnt was which of them produced the food he liked best. These must sometimes have been the ones which were hardest to get, and probably the ones which it would pay him best to tame.

Coolie of Szchechwan. He will carry loads of 200 lb. of tea for 150 miles.

There can be little doubt that early Man ate small animals such as snakes, lizards, frogs, squirrels. There are many tribes in India and elsewhere who eat almost anything that creeps, crawls, jumps, flies, runs or swims, to this day: primitive Man was not likely to have been more finicky about his food than they. Obviously it would be sheer waste of time to try to tame animals so plentiful and so easily killed as these small fry, which incidentally would at that time have been of no use for any purpose other than food. Besides, they would be difficult to keep. So Man reserved his talents and his patience for bigger game.

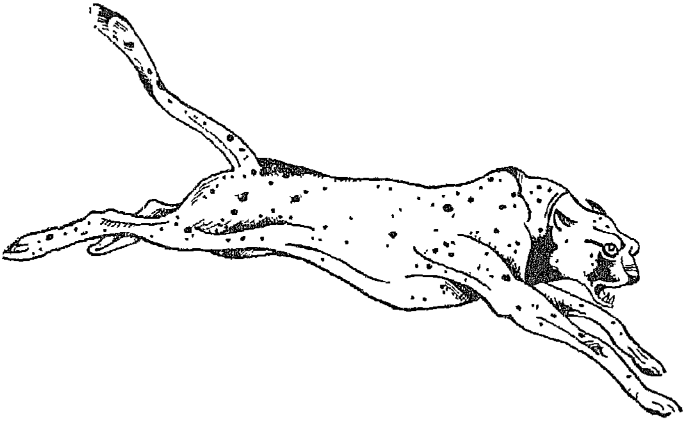
Looking at the very few animals – considering the total number available – he *did* domesticate, one is apt to endow him with a special and almost uncanny instinct for hitting on just those animals which could be most easily tamed, which would be most useful to him, and which would be most likely to vary and produce useful varieties! Look at the innumerable breeds of dog, of cattle, of fowls, even the considerable number of horses and cats!

On the other hand, elephants vary but slightly, and then it is a natural, not an artificial, variation, like the tuskless elephant of Ceylon. Camels vary hardly at all, the one-humped and the two-humped being distinct species confined to different parts of the world. The domestic yak of Tibet, in spite of being crossed with the Indian ox, varies chiefly in colour, size and degree of shagginess. One reason may be that, unlike most domestic animals, elephants, camels and yak have not spread all over the world. There are, however, said to be two varieties of yak, horned and hornless, quite distinct; but if so, little is known about them.

In fact, we are probably quite wrong in thinking that Man exercised any great acumen in selecting animals for a domestic life. *We* see them today, after more than 7000 years of domestication; naturally they appear docile and well adapted to their job. But who, looking at the wild boar in the mountains of western China, would imagine it to be an easy animal to tame? Who, watching the grey wolf trotting across the cold snow-chequered landscape at dusk on its way to rob the fold, would care to take it in hand and turn it into the faithful dog? Here another thought obtrudes itself. Animals, and as it happens, particularly wolves, even in these days, have been known to adopt humans. There are in India stories, unquestionably authentic, of 'wolf children' (and were not Romulus and Remus suckled by a wolf?). Thus both the belief and the event are ancient. As for variation, we do not know why some animals vary enormously and others hardly at all. Nor is variation confined to domesticated animals, though with artificial selection, if the animal is naturally inclined to vary, much may be done. However, selection will not *start* variation. Thus, to take a simple example, there is a species of leaf-eating monkey or langur (*Semnopithecus*) common throughout India, of which more than twelve local varieties or sub-species have been described.

On careful consideration one might perhaps come to the conclusion that Man had selected just enough animals for his purpose, and those which suited his requirements best. At any rate, nobody seems to have tried to improve on his choice since; all later efforts have been directed towards improving the breeds. We must remember that early Man, starting from scratch, was severely handicapped. He had the sense to see that he could not do much with the carnivores to begin with, so they had to be cut out. And yet he required *one* fierce animal as guardian. He seems to have chosen the right one; he may, of course, have chosen others, of which we know nothing simply because they failed him. Meanwhile, however, both the common wild cat and the cheetah were tamed, so evidently even the carnivores were not entirely hopeless.

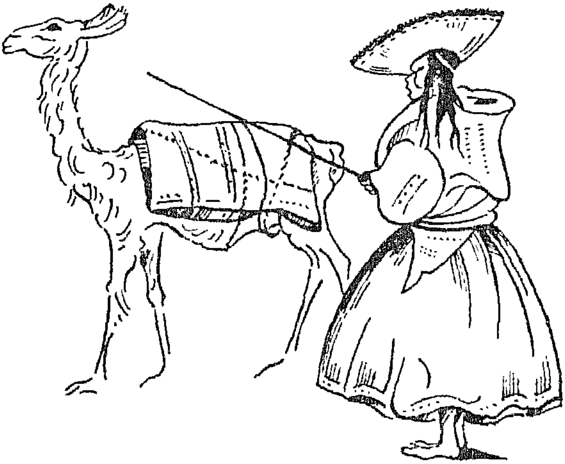
Man also wanted meat, and possibly milk and warm skins. Wild sheep, of which there are a fair number, and goats, which in the wild state are scarcely distinguishable from sheep, were an obvious choice. The pig was no doubt a delicacy, and later became useful as a village scavenger; cattle of various breeds were plentiful. Chance, too, may have played a part, as we shall see when discussing methods. Later Man wanted labour, so much so that every region in the civilization belt produced at least one draught animal suited to the climate – in north-west Europe the horse; in the Middle East the camel and donkey; in India the ox and the elephant; in south-east Asia the water buffalo; in the New World the llama.



Cheetah.

Can we with all our knowledge of about 3000 species of mammals, suggest anything better? The only certain way of getting the best animals was by trial and error, and as it may have taken several centuries even to tame an animal like the wild boar, there was not much margin for error. One may, indeed, be surprised that no deer, except the reindeer, and no monkeys at all, were ever domesticated; and that on the other hand the wild cat was. But after all, so far as one can see, neither deer nor monkeys would have been of much use in the labour market, and cats have their use to this day, and may have been much more necessary even a few hundred years ago. Besides, the cat is one of the very few carnivores small enough to be physically weaker than Man, and yet large enough to be of use to him.

In what order were our domestic animals domesticated? We have good reason to believe, but no proof, that the dog was the first, and cattle a good second. If we assume that the domestication of animals began some 10,000 or 12,000 years ago, it might be possible to discover the likely order from the known distribution of animals – and of Man – at that time. There are several possible lines of research, such as the drawings in caves, hieroglyphs, and so forth. We may be sure that the domestication of animals and plants occupied Man for a thousand years or more. It would certainly have taken centuries for them to attain their present world-wide dis-



Red Indian Quetschua woman of the Peruvian mountains with her llama.

tribution. Actually, of course, very few of the few domesticated animals have spread over the whole Earth. Cat and dog did not reach Australia and New Zealand until the eighteenth century. The inhabitants of the several continents had to domesticate such animals as they found – which also suggests the possibility of several centres of origin. But, of course, Man himself may have carried the *idea* of domestication from a common centre during his wanderings, long before he was in a position to transport the animals themselves. Few of the early domesticated animals could have spread far; the elephant of tropical south-east Asia, the camel of the desert belt, the reindeer of Lapland, the 'camels' of South America, could by no means have spread over the Earth; all of them are too highly specialized. And what chance had the few inhabitants of Australia and New Zealand to domesticate any useful creature? The only wild mammal in New Zealand, when discovered by the West, was a bat! As it happens, Man exterminated the moas of New Zealand and the elephant bird of Madagascar within the last millennium.

But it is hard to believe that animals like the reindeer and llama, peculiarly adapted to lands which were probably amongst the last to be occupied by Man, can have been domesticated for more than 7000 or 8000 years, if so long; they probably succumbed to him long after the dog, which, as we have noted, may have been domesticated for 10,000 years or more. It is commonly assumed that it must have required an enormously long time to domesticate the first animals. It may have been so; but it is likely that some animals, cattle and sheep, for example, may have been quite easily and quickly tamed – they may even have co-operated. From taming to domestication is but a step. Moreover, wild animals unaccustomed to Man are not afraid of him, and so do not flee at his approach until they have *learnt* by bitter experience to fear him.

The catching, taming and domestication of wild animals, therefore, would not have been so difficult in the beginning, when there were many animals and few men, as it is today; nor would it take so long. Domestication may have been going on, in one part of the world or another, for one or two thousand years; but the domestication of a particular animal in a particular place may have required no more than a few centuries.

Primitive Man, without weapons, is often pictured as living in terror of wild animals all his life. It is supposed that because he had no firearms he went about in perpetual danger. This is almost certainly false. Carnivores, including even the savage sabre-toothed tiger, which roamed the plains of Europe, lived amongst huge herds of ungulates – cattle, deer, horses, antelope, sheep – and it is most improbable that they would have bothered Man very much. Occasionally, no doubt, there were 'incidents'.

It is true that today many people, in the tropics especially, are killed by wild animals every year – not all of them accidentally. But today the conditions are entirely different. Today, human congestion, the changing face of the landscape, and the temptation offered to wild beasts by crops and tame herds where all natural cover has been stripped from the landscape, is irresistible. Besides, the ruthless slaughter of game which is the natural prey of carnivores, by Man, makes attack on domestic animals, and eventually on Man himself, inevitable. Yet for my own part, in the course of many years wandering in the wilder forested mountains of south-east Asia, generally unarmed, I have come unexpectedly upon very few dangerous animals. I once surprised a tiger stalking a herd of grazing cattle, so that it rose and bounded away up the hill, presently to turn round and sit on its haunches like any cat, eyeing me with no affection. Once also I came upon an elephant (I have heard others, especially at night) sauntering along the jungle trail that I and my coolies were following. We kept discreetly behind it, at a reasonable distance, until in the fullness of time his lordship wandered aside into the deeper forest out of view, allowing us to pass. Twice I have come round a corner face to face with a black bear standing up, and both times it made off in one direction while I took the other. I have seen wolves more often, but never very close; on one occasion a 'pack' of three. And once in a jeep I almost ran over a 12-foot cobra on a rough mountain road – it was lying in the middle of the track, but raised itself and spread its hood as we drove at it. I have, of course, surprised – and been surprised by – many smaller and less aggressive creatures, such as pig, deer, gooral, takin; but the entire list is not very formidable. In the Burmese jungle it is a rare event to see a wild animal by chance – except at night. But primitive Man, who inhabited the open steppes, must sometimes have lived in the midst of game, particularly in Africa.

The methods by which Man might have attempted the domestication of animals were, no doubt, such as would be used today. They could only begin with the young, with any prospect of success. The young of wild animals may be found by chance, or they may be captured after killing the mother. Dying animals may occasionally be picked up and nursed back to life.

Many years ago, while ploughing knee-deep through alpine scrub on a steep hillside in the wild Mishmi Hills (I was looking for Rhododendrons), from almost under my feet sprang a gooral. It bounded away only a few yards, turned, and stood still staring at me. This was surprising, as the Mishmis hunt gooral, and the creature must have been frightened and suspicious of my purpose. Yet it stood its ground. I heard a sound close to me. The bushes moved and I looked down. Right at my feet was a baby gooral, a day or two old. The mother having now bolted out of sight, I picked up the baby gooral, and not without difficulty carried it in my arms back to camp some little distance along the ridge. It lived for two days only, though we fed it on our precious tinned milk.

Many young animals are found like that, especially by children, and survive. Children are fond of nursing young animals; the beginnings of domestication may sometimes be traced to them. There are, indeed, various ways in which young and helpless, or perhaps sick, injured or exhausted animals are brought into the fold and fed. Taming them must undoubtedly be a gradual process; there is little room for a belief in sudden conversion; although legends and fairy stories abound in gratitude tales in which an animal's life has been saved by pulling a thorn out of its foot, or some such operation. Even the tiger figures thus in Indian fairy tales.

There is another way. In times of flood, and still more of fire, animals lose all sense of fear save that of the immediately threatening death. Then indeed, if at no other time, the wolf shall lie down with the lamb – though in the present context 'lie down' is not, perhaps the *mot juste*. From his river valley caves, Man may have rescued animals from fire and flood, thereby forging a bond of friendship by safety. Nor must we forget that there are not a few people today who seem to have a mystic power over animals, who can, as it were, get on to their wave-length and soothe them in some manner not understood by most of us.

The domestication of animals, then, gradually relieved

Man of some of his anxiety, and of much physical labour, thereby giving him leisure. Further it provided him with an almost perfect natural food, namely milk. It may, however, be questioned whether the use of animal milk *is* natural – many people today regard it as a dirty practice to drink milk, an idea which may easily have sprung up as the result of epidemic disease. The Chinese, for example, will not touch it.

But if we regard the domestication of animals as following three priorities – (i) protection, (ii) meat (and clothing), and (iii) labour – we shall probably be near the mark. Animals were not kept as pets – that is an almost modern development. They were, and still are in the greater part of the world, slaves. Protection came first, hunting second; or perhaps *vice versa.* It was easier to train a dog or a cheetah to hunt one's food than to hunt it oneself; it was even easier not to hunt at all, but to eat beef or mutton.

We may then reasonably suppose that the idea of recruiting wild beasts as allies began to occur both to Palaeolithic and to Neolithic Man some 10,000 or 12,000 years ago; further, that several species of Man himself were by that time fairly widely distributed over the more habitable parts of the Earth, mainly in the drier parts where crops would need to be irrigated, and in the cooler parts.

There is no reason why such an idea should not occur to different people in different parts of the world. But not many parts of the world were habitable until civilization had progressed beyond the domestication of animals and plants. Once an animal like the dog or the cat was domesticated, the idea of domestication spread like any other cultural idea; for, unlike the horse or the elephant, the dog and the cat could accompany Man in a small boat. The fact that if it was possible to domesticate one animal it might be possible to domesticate another would not be lost on a tribe which hitherto had been without such help.

In modern times the tendency is to *farm* wild animals without troubling to domesticate them, some of the same results being achieved. Thus foxes are farmed in Canada and in Norway for their fur, and snakes in Africa for their skins as well as for venom.

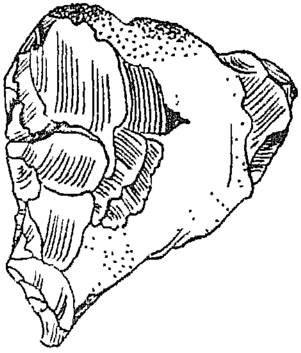
By the time Man had begun to domesticate animals and plants, say 8000 or 10,000 years ago, other ideas were crowding upon him. One of these, it appears likely, was the *machine*, a device not so very different from a tool, to help him with his everyday work; especially his agricultural work.

CHAPTER VIII

THE MACHINE

MAN is a tool-using animal. He makes and uses tools by virtue of his having hands. There is evidence that his hands at first developed faster than his brain; but hands and brain, over a long period, developed together. The possession of hands enables Man to grasp a tool firmly. This ability he shares with the great apes and many lesser monkeys; but it needs brain to *devise* and make a tool.

What jobs, then, did early Man do using his hands? Food-gathering for one, and that the most important. This would imply digging, as well as plucking grain and fruit. Throwing and striking with a club, as well as the mere grasping of objects – all these things the great apes can do today, and from the beginning Man would do no less. But no ape ever *made* a tool.


Edge-chipped flint attributed to Eolithic time.

Man had from the earliest beginning of his career made for himself tools, fashioned painfully and clumsily out of such stone as lay to his hand, notably flint. Eoliths, the earliest known tools used by sub-man are called, and they are crude enough. Yet they result from an idea, and needed a brain as well as hands to rough-hew them. Eoliths may possibly have been made a million years ago.

Is there any difference between a tool and a machine? Can we accurately distinguish between them? Let us be quite clear what a machine is. It is a device for applying power, or changing the direction, speed or force of power, in order to do work. And a tool? It would be difficult to frame a definition which was substantially different from that just given. A tool also is designed to do a certain *kind* of work, either because the hands alone cannot do it all, or because they cannot do it so well, or so quickly. The simplest tools are grasped in the hand, and the simplest application of power is man-power. But the simplest tool may – and generally does – do the work by reason of its being a simple machine, worked by hand. No obvious mechanical principle is embodied in the hammer, scraper for cleaning skins, or awl for boring holes. But the straight lever, which must have been in use many thousands of years ago, is, of course, a simple machine; and many tools are actually levers. From a tool, such as a hammer, to the simplest machine, such as a pivoted lever used to lift water from a well, seems a fair stride; from the simple machine worked by man-power, to the machine worked by animal power or, still more, by some external power, is a much longer stride. But we must remember that there is a regular transition, nor can we say just where the tool ceases and the machine begins. Once the first machine, worked by hand, had been devised, Man would begin to ponder some other method of working it; and the domestication of animals which could do it would give him the first clue to power.

Originally the machine was a labour-saving device, a means of applying less power to get the same result. That is its intention. Later, when the theory of power or force was better understood, it became a means for changing the direction, or applying a measured amount, of power. But to begin with, it saved labour; and who more than primitive Man, whose entire life almost was given over to the search for food, needs a rest!

In the beginning all power was man-power. The domestication of animals to do work formerly done by Man was an enormous improvement. But obviously animals could not be taught to make tools. A long time would elapse after the domestication of the first animals before they were taught to take Man's place at the wheel; and Man must first design and make the machine, which he doubtless did before even the first animal was domesticated.

The domestication of animals, then, freed Man for other work, besides giving him much needed rest. It was to become of great value to the cultivator; indeed, it represented the difference between mere gardening and agriculture. But we can hardly believe that it came early in Man's history. Man had been toiling for many thousand years before he obtained even this small relief.

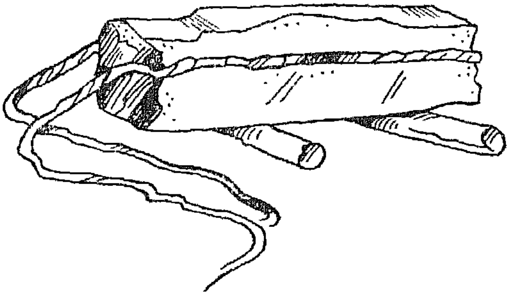
Yet there is plenty of cultivation in the world today in which neither animals nor machines take part. All the work is done by men, women and children – as in the mountains of Burma and Assam, for example. Theoretically, with the domestication of animals far advanced – and there is little reason to believe that any more wild animals will be domesticated than are domesticated today – men need no longer drag other men about in rickshas, lift and carry huge weights, or put their shoulders to the wheel. Yet we know that they do. Now, with the invention of the power machine, even animals can have leisure; no longer – again theoretically – need they pull ploughs, draw carts, or carry heavy loads over long distances. The machine can do all these things, and do them more efficiently. Clearly, what is theoretically possible is not always entirely practical. The world's work can never be run entirely by machinery, even though the machine could do far more of Man's work than it does at present. Nevertheless, it is true to say that the machine enabled dead matter to do what hitherto Man had been compelled to do by the sweat of his brow – or by the sweat of his domestic animals – and much else besides which he could not do unaided. It opened a new chapter in the history of the world. The invention of the first machine worked by outside power ushered in a much greater revolution than the Industrial Revolution of yesterday. As to that, the all-metal power machine, too, had to be fed, and as vast new industries sprang up, there seemed to be ever more and more hard labour both for Man and beast. Man also has to build the power machine, and a glance at modern industry hardly suggests that he has been relieved of toil and sweat, even after 25,000 years, by the invention of the power machine. Evidently he never will be. Indeed, it is less highly civilized Man who today has a fairly easy time of it, while machine-using Man works like a galley slave – a paradox one could hardly have foreseen.

The simplest tools and machines have to be made of something, and a limit to what can be invented is set by the materials available. As we shall see when we come to consider the subject of raw materials, these were formerly few. The first tools were made of stone and wood, and the first machines also, even power machines. Little else was available. The recognition and extraction of raw materials, and the order in which they came into common use, is the story of civilization.

How Man came to make tools, how he first began to construct the means to move and lift weights – the rolling log for moving heavy stones; the inclined plane which enabled him to raise a weight by means of a horizontal pull;

the wedge, which enabled him to split a log which he could not tear open with his own strength – we can only conjecture. These things may have occurred to some unknown genius a very long time ago; or they may have been the result of some accident.

We shall probably be correct in assigning the first labour-saving devices to a settled agricultural population and connecting them with such work as the grinding of corn and the irrigation of crops. That is to say, the first machines were agricultural machines and were constructed of wood and stone. It is not unreasonable to suppose that the first power machine ever made was for the purpose of husking grain. If that is true, it cannot be more than about 10,000 years old and may be a good deal less; modern, in fact, compared with the whole time we are contemplating. Indeed, the first power-machine may not have been in use until after the first fields were being tilled – that is, after the domestication of cereal crops.



Rollers for moving a heavy stone. Neolithic period.

But Man had been using tools, some at least of which were simple machines, for thousands of years before that.

One of the simplest machines ever invented was the straight lever. A man digging up a plant with a pointed stake, forcing it into the ground, then pulling it towards himself so as to lift up the earth round the plant, is using this kind of lever. The pivoted lever was a later invention. In this, the short arm of the lever carried a bucket dipping into a well, and was balanced by the longer arm, which was pulled down by means of a string, thereby raising the bucket when full of water. This, too, is connected with agriculture, and can be seen at work today in Egypt, India and many other countries.

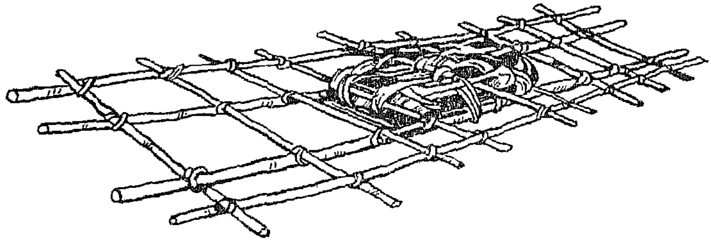
It would have occurred to Man quite early that, his strength being limited, two might be able to do what one man alone could not manage. This would be obvious when it came to lifting a weight, for example, or dragging a rock. The advantage of co-operation to do a simple piece of work must have dawned on the family or the tribe early. But Man's efforts – as those also of his domestic animals – are limited not only by his comparative weakness, but also by the practical difficulty of concentrating more than a few men on one particular job. If one man cannot lift a heavy weight, two or three men may be able to do so – if it is big enough for them to grasp. On the other hand, if one man cannot hammer a lump of iron to the thinness of a sheet of paper, neither will a hundred be able to do it, in any calculable time. In other words, a job cannot be done simply by the indefinite multiplication of man-power working on it – the mere *sum* of the strengths of several men.

This is the sort of problem that must frequently have presented itself to early Man, and the answer to it was gradually found, to some extent, in the further development of tools and simple machines, such as the lever, wedge, inclined plane, and even the more complicated pulley, most of which machines are in everyday use in our own homes. We must be cautious, however, in asserting that it is impossible to multiply man-power; that what several men cannot do, a multitude cannot do, just because they cannot all apply force at the right point. It is just here that Man had the wit gradually to evolve means to overcome exactly that difficulty. Although man-power cannot, for obvious reasons, be multiplied indefinitely to add up to one big power, it can be concentrated, up to a point, in several ways. It is probable that this was the earliest means of doing heavy work; it involved nothing more than the simplest machines.

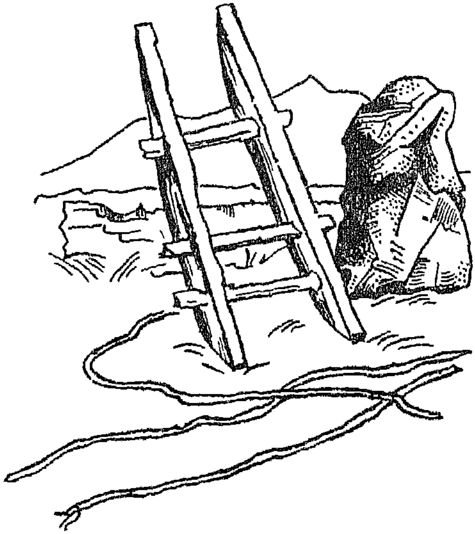
There is no mechanical contrivance by which a great number of men could lift the Pyramid of Cheops. Even a million men each carrying a load of 50 lb., though they would be lifting between them over 22,000 tons, could not raise a stone weighing 22,000 tons, for the reason that no material strong enough to drag, or lift, such a weight was available. Even when such materials have been discovered, their weight is such that the combined strengths of still more men must be added to the original number required, making their addition yet more difficult of application, and needing still more tackle, and so on in a vicious circle. But the multiplication of man-power is, of course, possible to a limited extent. We have all seen six or eight men bearing a heavy coffin on their shoulders, or carrying a beam. In China far heavier coffins, sedan chairs, and machinery, are carried by numbers of men at a quick trot by means of an elaborate arrangement of long and short bamboo poles supporting each other, which distribute the weight, the two ends of each pole ultimately resting on the shoulders of two men.

Some of the Naga tribes of the Assam hills move a heavy boulder by first building it into a bamboo frame. A team then raises the frame – perhaps five men abreast in twenty rows – and in this manner a hundred men will carry the rock a considerable distance to the village. The Angami

Nagas can move even heavier rocks by means of a wooden sled, beneath which logs are thrust to act as rollers. Several hundred men will then drag on the cane ropes. Such outwardly ant-like feats of co-operative strength, where every



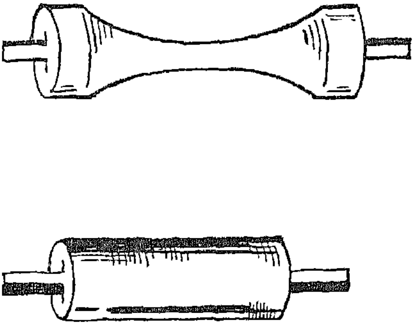
Bamboo frame, used by the Naga tribes of the Assam hills for moving heavy boulders.



Sledge on which rocks and stones are pulled by the Angami Nagas.

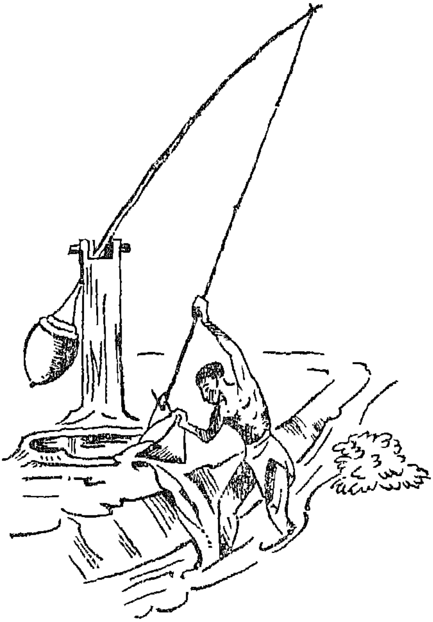
man does the same thing, have been performed from very early times – witness the building of the Pyramids and of Stonehenge.

As an example of a simple machine worked by one man, take the well lever briefly described on p. 124. It consists of a wooden pole 12 or 15 feet long, pivoted at a point (fulcrum) about a quarter of its length from one end and supported on a post some 5 feet high. A stone is fastened to the end of the shorter arm, while to the longer arm a bamboo rope long enough to reach to the bottom of the well is attached. A bucket is tied to the free end of this line. The combined weight of the short arm and the stone is equal to the weight of the long arm and the bucket filled with water, so that the lever rests with the stone on the ground, and the bucket in the air. An upward push on the stone sends the bucket to the bottom of the well, and a slight pull on the short arm is then sufficient to raise the bucket full of water through 20 or 30 feet. Thus the small arc described by the stone is magnified several times over by the bucket.



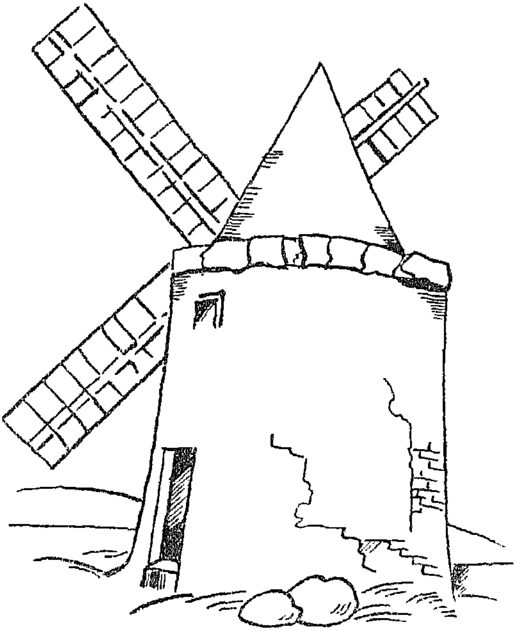
Rollers for fitting to a sledge or a stage.

Animal power to some extent relieved Man of hard labour, but it brought him little leisure. Already there was more work to be done. The simple machine enabled him to do work which without its aid could not have been done at all. If a simple machine, such as a wedge, is interposed between muscular power and the point of application, the job may be done for a lesser expenditure of energy by changing the direction in which the power is applied. Or a time factor may be introduced – as in the pulley – which reduces the amount of energy necessary at any given moment by increasing the time during which it must be applied.



Pivoted well-sweep, a *Mesopotamia invention* introduced into Egypt about 1400 B.C., still in use for irrigation.

Then – perhaps as the result of thought, perhaps as the result of some happy chance – came the machine worked by outside power, such as wind or water, and at long last, after many thousands of years of labour, Man began to taste the delights of leisure, and of rest (which is not quite the same thing). And not of leisure only, but of increased comfort.



Windmill.

At first sight it may seem absurd to class the first stone-and-wood power machines – wheels moved by wind or water – with the complicated all-metal power engines of today. Are not these simple engines – the self-turning water wheel, the self-operated water lever used for husking grain –

merely a slight improvement on their hand-worked predecessors, fit only to be compared with the simple tools and machines of still more primitive peoples? How can one possibly class these wooden engines with the power engines of today? Surely, you say, it was the substitution of *metal* for wood and stone, leading to the wonderful engines of today, which divides ancient Man from modern Man.

By no means. It is the *power* machine – the water wheel and the wind wheel – not the improvement in construction materials that was revolutionary, and it was the recognition of natural power which paved the way for the self-acting machine, thereby relieving Man of so much of his burden. A water wheel or a windmill derives the power which turns it exactly as a steam engine or, ultimately, a dynamo, derives it – from outside itself. The difference is simply that the natural power which turns the water wheel is more capricious and less under control than the power which drives the steam engine.

Thus Man gradually came to realize that he himself could control and measure out power, and so gain command over the forces of nature. The steam engine is less than 300 years old; but the water wheel is probably more than 6000 years old; its invention was a tremendous forward step.

Let us then look for a moment at this revolutionary time when tool-making Man stood face to face with power and knew that he was master.

CHAPTER IX

THE RECOGNITION OF POWER

POWER is like fire. It is something that exists apart from ourselves, inherent in the world we know. Yet it is more elusive and remote than fire, for it is recognized only by its effects. To produce power, to raise and control it at will, was far more difficult for Man to achieve than dominion over fire. For fire itself could be *seen*. Until Man had some glimmer of the connection between cause and effect, it was impossible for him to recognize that there was such a thing as power. It was not necessary always to assign the right cause to a result – the history of Man is littered with false causes. But the sequence 'cause-effect' had to be established before Man could hope to make any headway with power, or even recognize it.

Let us see how the recognition of power may have been achieved. Nowadays we all know in a general way what is meant by power. Moreover, an extension of the word gives us 'Power Politics', the 'Great Powers', and other ideas. Anyone who lives in a modern residential district, and who enjoys the benefits of communal life, sees evidence of power all round him day and night. He may not consciously analyse it, may scarcely be aware of the various kinds and sources of power which smooth his path through life, because he is accustomed to take it all for granted. Once a quarter, however, when he pays his electric light bill, water rates, gas bill and other such items, he will be at least momentarily reminded of their existence. For the rest of the time, in a placid manner, he enjoys the results, and bitterly resents any failure in their functioning and the routine of comfort. Every day he turns a tap, and clean water flows; it is much more than clean – it is *pure*. He presses a switch, and the room is flooded with light; turns another tap, and lights the gas stove on which his dinner is cooked; twiddles a knob and listens to political speeches, music or propaganda; twists a dial, and speaks to his friend who lives a dozen miles away. In the morning he boards a train, and is whisked comfortably to his work twenty miles off. These are no small triumphs.

Then one winter's day during a cold snap his pipes are frozen, and he turns the tap in vain. There is a thunderstorm and his telephone is dead – his wireless set too much alive. The electrical engineers go on strike, or a power-cut euphoniously described as 'shedding the load' is ordered by the Government, and he is left fuming in darkness because the current is cut off (but perhaps he forgot that small matter of the quarterly bill!). It is all very disagreeable, but let us hope it didn't all happen to the poor man at once!

But to drive home the lesson, worse is to follow. There is a railway strike, and he cannot even get to work – at least, not by train. (Some of us, perhaps, could just bear such an enforced holiday on full pay for a short time.) Thus his whole routine is upset, disarranged, and he himself made very uncomfortable, and all because power has been cut off. Clearly, power plays a big part in his life.

If, however, instead of living on the outskirts of a great city and travelling to work by train every day, our little man lives in a cottage in the country and works in the adjacent fields, the pattern is rather different. Perhaps he draws water from the well every day and carries it to the house in a bucket. There is a fire in the kitchen range, and one of his jobs is to chop wood for it. When night comes he lights an oil lamp. He cycles to his work on the farm, and drives a pony and trap to market four miles distant.

Not much power in evidence here, other than man-power, you say. Yet it is easier for the countryman to be conscious of power than it is for the townsman. For though the countryman is less dependent on *controlled* power than is his neighbour of the town (and incidentally, less affected by strikes, Government 'cuts' and breakdowns in the public services), and though power is not doled out to him by companies from the communal supply at a fixed rate – *he* never has to put a shilling in the slot – he is in closer communion with the forces of nature, that is, with power in the raw and, in fact, the ultimate sources of all power. Hence he is more aware of its existence. He sees the river in flood, hurrying boughs and leaves along on its surface and clawing at its banks; goes out into the storm and feels the force of the wind; sees the lightning running like quicksilver down the sky, and learns at first hand of its power when it splits open a tree at a blow. Thus you would have less difficulty in recognizing power if you lived in the country than if you lived in the town, where power is so conveniently laid on; that is, if you can recognize it when you see it, or its effects.

But primitive Man had not our knowledge and experience, and we may well ask: when did *he* in fact recognize that he was surrounded by forces far more powerful than himself? *We* recognize the sources of natural power because we are familiar with man-made power. But there is little reason to think that early Man did so.

Man is continually confusing cause and effect. *Post hoc ergo propter hoc* is the creed of the million. To savage Man events were inconsequential; every event was isolated. It requires a mental effort, and memory, to recognize the relationship between cause and effect, and to classify happenings; and early Man had not yet, and could not acquire, the accumulated experience to formulate general laws covering a number of events. Thus the fact that the results of power were visible on every hand was not readily appreciated by him.

Man's first acquaintance with power is the consciousness of his own strength. He lifts a log or a heavy stone, strikes a blow, pushes over a tree or a rock. He has to rely on his own strength; no other source of power is open to him. These things he does in no idle mood, but in order that he may live. He tires himself out. Is there, he wonders, no rest? Some relief, perhaps, is obtained, after a long apprenticeship to toil, by the domestication of animals, though for the most part they are auxiliaries rather than substitutes. It is interesting to observe that the search for power which might bring leisure to Man and lighten his intolerable burden, had in later ages deep-seated social results. It brought about slavery, the owning of human beings in place of domestic animals to do work. Domestic human animals were easier to handle than domestic beasts. They had more intelligence and could learn more quickly.

For tens of thousands of years, before he domesticated the first animals, Man had recognized no power other than that inherent in his own muscles. One may hazard a guess that for centuries after the domestication of beasts of burden to help him in his work, Man still relied on muscle power, assisted by such tools as he could make of stone and wood. But there came a time when, imagination soaring beyond the power at his command, he wondered vaguely whether there was any other sort of power. *Had* nature any power, apart from Man or animal? Was there, perhaps, any universal, ever-present form of power?

We might perhaps ask *our*selves that question, and make certain that we know the answer; for much hangs on it. Are we, today, clear in our own minds what raw power *is* available on this Earth, has been apparently from the beginning of time, and will be, so far as we can see, until the Earth is as dead as the moon, a frozen stone? Many of us, perhaps, are not quite sure of the answer, or fully aware of this inherent power, although we shall probably agree that it does exist when it is pointed out to us. It must have dawned very gradually on Man. Let us, then, inquire a little more closely into what power there is, outside Man himself, even if we cannot quite understand how he at last came to recognize it and turn it to his own advantage.

Power is either life-power – that is, man-made – or it is 'natural' and inherent in dead matter. From the earliest times Man saw around him what we see around us – the force or power exerted by all moving matter but most obviously by wind and water. Wind is a mass of moving air, and though savage Man would not recognize air as matter at all, he could not fail to appreciate the results of its motion. Wind blows down trees, and may even blow down Man himself, or lift him up like a leaf and whirl him aloft. True, wind is not always blowing at any given spot, or anyway not appreciably. But if we regard a considerable area, particularly where land and water meet, we shall not have to wait long before becoming aware of breezes. We shall see waves too.

Wind, however, is invisible, and is recognized only in its results. But there is another form of natural power which is visible to the eye, and which primitive Man certainly saw in the course of his wanderings – the power of moving water. Indeed, when primitive Man began to settle down in caves, he settled by rivers, or along the sea shore, and so must have become familiar with this natural force. The river in flood is very powerful; so also are the waves of the sea. Man views with alarm the water rushing along as the river rises irresistibly foot by foot; he sees it toss aside or push before it leaves and twigs, and presently sticks and logs, while here and there the bank caves in with a loud noise. He sees the angry wave fling itself up the beach, the creeping, irresistible tide setting afloat objects which had lately been high and dry. These things happened so regularly, and so often, that Man must long have been familiar with them. Only when they were unusually violent was he afraid.

There are more awful manifestations of power in the world, however, than flood or tidal wave – signs of instability which might cause the stoutest heart to quail. I refer to the earth tremor and to the volcanic explosion. The solid crust beneath us trembles and splits open; the volcano, which is a safety valve to the red-hot interior of the earth, blows the lid off, the pot boils over, and liquid rock pours out as lava with a dreadful roar, bringing death and destruction to everything that lies in its path. Man must not seldom have seen such terrifying manifestations of power, and felt completely helpless – as he still does today. Never would it occur to him that he could turn the ungovernable fury of the reeling earth to his account, or imitate the lightning stroke. Nevertheless, in the course of ages, he must have become aware of the power being squandered all round him, and especially by those usually gentler and more regular manifestations of it to which I have already referred – the running stream and flowing wind. Gradually he became conscious of the fact that there were sources of power outside himself, and to the bold pioneering spirit who appeared here and there down the ages may have occurred the thought: cannot I harness a fraction of this colossal power to help me do the things I would like to do, had I the strength? When Man first recognized the existence of power apart from his own strength and that of his domestic animals, he had already taken a long step forward.

Meanwhile he was becoming skilled in the invention and use of tools. Some of these were, as already noted, simple machines. Yet it is a long step from the simple muscle-operated machine to the power-driven machine, no matter whether the power be derived from the wind or stream, or from combustion. The difference in the result, too, is incalculable.

We must picture Man, therefore, possessing fire, domestic herds and watch-dogs, wearing skins, and possibly other clothing, cultivating crops, building the first villages. He has invented, or is about to invent, writing, pottery, weaving – in a word, he has invented civilization. And into this rare new world of 8000 or 10,000 years ago steps – *power.*

Let us now consider the possible sources of inherent power, visible to Man by their effects on him or on his surroundings, noting that anything which moves exerts force, and because it moves, does work. Force may also be exerted by intangible things which do not move, such as *gravity.* The recognition of gravity as a force has nothing whatever to do with how it works, what diverse happenings it embraces, or why. It was harnessed indirectly and unconsciously in the service of Man thousands of years before anyone knew anything about it more than the simple fact that a weight, unsupported, invariably fell to earth. The savage knows not a thing about gravity, but he does observe, as we all observe, that he can let fall a stone on to a nut or a shellfish and crush it. He would notice, too, the falling rain, the flying clouds, the flowing river. In short, he must have seen what we, even as children, see today – the power or force in all moving matter: in wind, which is air in motion; in the ebb tide and the flood, in waves, and flowing rivers, which are all water in motion, pushed or dragged by power; in earthquakes, avalanches, and landslides, and similar moving masses of rock and snow.

We know that tides, avalanches and rivers depend for their motion on what we call gravity; but the savage knows nothing about gravity, and while recognizing that he could crush a resistant shellfish by dropping a heavy stone on to it, he would not recognize that the same power which pulled the stone down also pulled the sea out, and exposed the unhappy shellfish to its fate.

Early Man, looking about him for relief or help in his perpetual toil, had first to consider what sources of power were available to him. But though he saw the wind blowing the trees, he would be just as likely to think that the trees, waving their arms about in anger, caused the wind. Moreover, the men who saw the avalanche would not be the same men as those who watched the ebb and flow of the tides, or the creeping lava flood. There was no means of comparing notes. The accumulation, comparison and classification of experiences took many thousands of years.

Thus everything points to the likelihood that it was a very long time before Man recognized the existence of *any* power outside muscular power, or tried to harness it. Moreover, the very idea of harnessing wind or water – of capturing, as it were, and controlling a portion of its strength, in order to make it do a particular job of work – must have been a long time coming to the surface. A certain minimum knowledge of raw materials and of simple working mechanics had first to be attained before that could be done.

Without formulating any clear ideas on the subject, he would remark how a stone falls to Earth, and that it will crush what lies beneath it. And so he used stones to crush and hammer things – but even monkeys do that. Could he make further use of that power for his own ends? He had to husk the grain; could he devise other means to do it? It seems to me not unreasonable to suppose that the crushing of grain was one of the first things he *did* learn to do with the help of power.

While savage Man *may* have made use of the wind and the flowing brook as sources of power, there are other manifestations of Earth's inherent power which he would not recognize as such, and could not have used if he did. As already remarked, the heat of the sun is a form of power; it evaporates water, the vapour rising with the air currents; it heats the sea and the land, giving rise to atmospheric currents which are largely responsible for the winds. Again, lightning is a form of power, and so are all volcanic phenomena. Yet it is probable that savage Man would regard as power only such natural manifestations of it as he himself could put to good use – gravity, in the shape of a falling weight; possibly wind, and running streams, all of which are available without any special knowledge or calculation. What use he made of them we shall see.

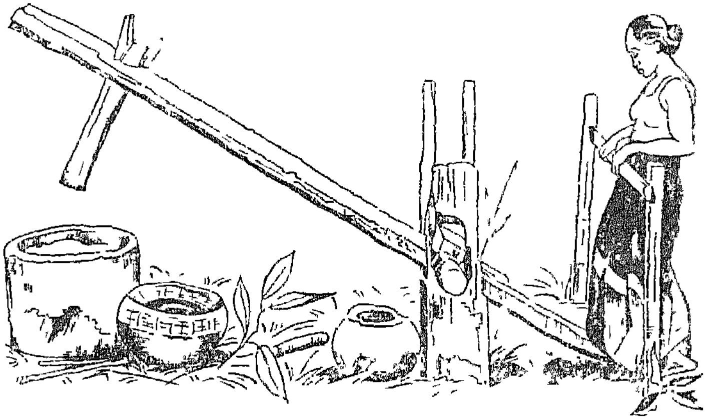
We may be sure that he would not investigate earthquakes, volcanoes or lightning. The first two would be rare events, perhaps unique in a lifetime, and terrifying. Except for a few communities which might live in the shadow of an active volcano, very few persons would ever see an eruption, experience an earthquake, or for that matter witness the fall of a meteorite on to the Earth; and these dangerous events would be regarded as having no connection with any other experience. That the results of power are visible all round us is, therefore, not necessarily and immediately appreciated by Man. He does not necessarily connect cause with effect, and rarely with the right effect. Even gravity would be overlooked as a source of power, and in fact it *was* overlooked until nearly the end of the seventeenth century. Thus for thousands of years the sages had had nothing to say about it, though it was, so to speak, right under their noses. Of course, to recognize a common denominator in the falling meteorite, the sliding avalanche, the revolving moon and the rushing river, was far beyond the range of savage Man's comprehension. But did that really matter? Man was concerned with *results*, and so long as stones dropped and brooks flowed, the higher mathematics of it – or even the lowest – could go hang. Man was as unlikely to get useful results from trying to harness the force of the tides as he was from the moon which rules them, so the underlying principles were no concern of his. He did not need to discover the law of gravity.

The only form of power that animals other than Man recognize is their own strength, and very few animals co-operate to combine their individual strengths into one big strength. Many of us, however, have watched a gang of ants moving a large object. But there the ant, though a living thing, has itself become part of a machine.

The simplest machine is, as we have already seen, no more than a tool, and unquestionably the first machines were tools. Man used tools from the beginning – even sub-man did that. So that the simplest machines, such as the lever, wedge roller and inclined plane, were necessarily worked by human muscles, at a later date by animal power, and finally by some external power such as running water or wind. It is fairly certain, then, that the simple machine came long before the recognition of external power as a means to work it, that is, before the application of power to the machine.

But how, one may ask, would the idea of even the simplest machine occur to the savage? Are there any 'natural' machines at work in the world, recognition of which would give him a clue? Can any wild animal be said to use a machine, or even a tool, for any purpose whatsoever?

We can most readily dispose of the second question first with a decided 'no'. For though the great apes and other monkeys have an opposable thumb and can grasp an object almost as easily as can a man, they do not habitually use tools, even though they may use a stone with which to break a nut. More commonly perhaps they beat the nut on a stone. In fact, one of the most obvious differences between Man and



Lao woman of northern Siam operates a primitive maize-husking mill with her feet.

beast is that the former only is a tool-using, tool-making creature. Nevertheless, the great apes show the first glimmer of tool-using.

The recognition of animal muscles, for example, those of the forearm, as working on the lever principle, is clearly far beyond savage intelligence. Hence it is very difficult indeed to understand how the idea of mechanical aid first rose in Man's mind. We may guess, however, that its invention was empirical. Any trick or device which enabled Man to do work more easily implied the use of a simple machine, that is, of mechanical aid. He still had to do work and use his own energy ; but the tool was a help. He did not realize the principles involved, nor did he need to. (The most crassly ignorant today can drive a car.) The savage knows no mathematics; but he can find out for himself by trial and error just how much he can lift using a straight lever, whether to dig up a root, or to move a rock. He sees that the trick works, and discovers that it is easier to dislodge the plant by this method than if he simply grasped it in both hands and pulled.

So one must envisage men all over the inhabited world trying to do a number of simple jobs with the simplest tools under a variety of conditions. But beyond the fact that the first settlements, whether in caves or not, would have been along river banks or beside lakes, or on the coast not far from fresh water, and probably in dry climates, we have few clues to the desirable residential districts of the Earth, or even of Europe, 10,000 or 12,000 years ago; no clue at all to where those exceptional persons who had ideas lived – that is to say, where the use of tools began. It is easy to say that they were evolved; but you cannot evolve anything out of nothing. No doubt tools had a multiple origin. It is hard to believe that any single tribe had a monopoly of ideas. As soon as Man could grasp anything he would grasp stick or stone, if only to defend himself – which no doubt he had to do frequently. But, as we have seen, the apes can do this too, and it does not tell us anything about the invention of tools.

Tools and machines, however, are not ends in themselves – or only very limited ends. They are means to higher ends, to make something else, or to do work. They enable Man to apply his efforts more economically, with less expenditure of energy and time, and to concentrate them in the right spot, often in ways unattainable by hand.

If we draw up a list of the possible sources of natural power on this Earth, we shall get something like this:

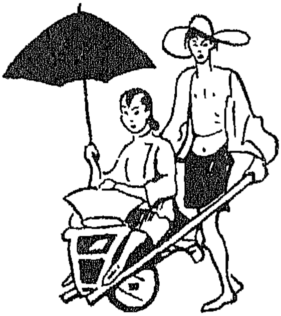
1. Gravity	Manifested in any falling object; in the flow of rivers, in waterfalls, glaciers and avalanches; in the tides and in meteorites.
2. Earth's magnetism	Manifested in the aurora.
3. The sun's heat	Manifested in ocean currents (apart from tides) and in winds, caused by the unequal heating of different parts of the Earth's surface and the distribution of sea and land, deserts, mountain ranges and so forth. There are, however, the direct effects of heat rays, and light rays.
4. The interior heat of the Earth itself	Manifested in volcanoes, geysers and other volcanic occurrences.
5. Electric storms	Manifested in lightning and its accompanying thunder.
6. Fire (combustion)	Brought about by volcanoes and lightning. Fuel, like coal, oil, wood, when burnt releases energy which can be made to do work.

Obviously, primitive Man could make no use of the majority of these. No one man, or even tribe, could have had any experience of more than a few of them. Such comparatively common events as lightning, meteorites and, of course, fire, would be known to almost every man, but very few would see an active volcano or experience an earthquake; fewer still an aurora. On the other hand, all would experience the commonest manifestation – of gravity – in the falling stone and the flowing river, without recognizing any bond between them; and all would experience the movements of the atmosphere, especially the more violent movement in time of storm. Only the wind, rivers and waterfalls could possibly be used as sources of power.

The discovery of metals and their possible uses was an essential prelude to the invention of the combustion engine. Was it a major discovery? Metals certainly enabled Man to do better what he had for thousands of years been doing not so well. Further, metal, replacing wood and stone in the machine, paved the way for the invention of the power engine, the discovery of electricity, and led to many other important results. The essential difference between the outside power machine and the combustion engine is that the output of power by the latter can be controlled; by the former it cannot. Apart from that, the combustion engine, in spite of the changes it has wrought, is simply a further development of the power machine. It never has given Man the leisure which might have been hoped for.

We have already noted that certain forms of power are inherent in the Earth as a planet, and we conclude that Man cannot create power. In other words, there is *no* power other than natural power, kinetic or latent, and Man can neither augment nor decrease it; all he can do is to transform it. The power is there, waiting to be tapped – in gravity, in the sun's heat, in the Earth's magnetism, and so on. All Man can do is to transform an infinitesimal fraction of it, convey it, store it. Yet most of it is beyond his reach, unused and apparently unusable. The huge store of energy locked up in the tides is practically wasted. In vain, so far as Man is concerned, do billions of tons of water swing to and fro twice in every twenty-four hours. The radiant energy of the sun is practically untouched. The atmosphere, consisting of billions of tons of gas, constantly in motion, is too unreliable; electric storms too violent and unpredictable; the inexhaustible reservoir of heat within the Earth's crust, too remote. Even the rivers of the world waste themselves. Every village in India could be not only illuminated, but flood-lit, by the water power of the Himalayan rivers. By far the greater part of the natural power available on the Earth is unused and spends itself idly, though not infrequently it gets the upper hand of Man and causes great damage to him.

It is probable that the power engine, the first of which might have been invented several thousand years ago, marks the high water mark of mechanization. One hopes so. With the land, sea and air conquered, what is there left? Only space – and time. One contemplates with singular disfavour a world so perfectly mechanized that the only form of muscular energy one need ever indulge in is the energy needed to twiddle a knob or press a button. The whole world and its infinite variety has now been brought to Man's doorstep. You can hear it!



A wheelbarrow.

CHAPTER X

THE INVENTION OF THE POWER MACHINE

THE simplest power-driven machine is hardly more elaborate than the simple machine used as a hand tool, and its design may be exactly the same as the design of a machine powered by a draught animal. There is no difference in principle between a horizontal water wheel pivoted on its axis, which carries a circular grindstone revolving on a fixed stone, and a capstan with a horizontal arm attached against which a bullock pushes. The gulf between them lies not in the machine but in the source of power. It was not difficult for Man to devise a means to grind corn, nor, once he had trained animals to work for him (a big enough step in itself) was it very difficult to substitute animal power. But to discover the existence of sources of power outside life altogether and to recognize the possibility of harnessing such natural power to do his hard labour, as described in the last chapter – *that* was indeed a revolution. The very simplicity of such a machine as, for example, the water lever for husking grain, suggests that it was the invention of a genius. Moreover, these power-driven machines made of wood and roughly hewn stone require swift streams to operate them, and are not such as one would find on the level plains, or on deltas. They belong to the foothills, and the foothills were probably occupied long after the plains. It is highly improbable that the oldest power-driven machine in the world, whether in China, in India or in the West, is more than a few thousand years old.

Although many centuries passed during which the only power-driven machines – all of them connected with agriculture – were made of wood, stone and perhaps leather, the power principle had now been firmly established, and the all-metal machine was already faintly foreshadowed. Still, it was not enough to have harnessed natural power. Man had yet to release power at will. The capriciousness of natural power, the almost insuperable difficulty of controlling it, and its irregular distribution over the earth (particularly the lack of it on the plains, which for other reasons were the most suitable regions for cultivation), limited its usefulness and delayed its invention.

At the same time, it is astonishing what a large proportion of the world's population contented itself with natural power to drive its machines, right down to the twentieth century. That hundreds of millions of human beings should have stopped dead, as it were, with the recognition of power, contenting themselves with its simplest application, while millions of people in another part of the world were turning knobs and pressing buttons to draw forth controlled and measured power as required, is an instance of the over-lap which each successive stage of culture displays over the next. It is scarcely remarkable, therefore, that in those regions of the world where the simple power machine reigned almost supreme, muscle power also survived as a major factor in industry, overlapping the invention of the machine by some thousands of years.

The harnessing of natural power to do work needs a machine no more complex than the machine worked by muscle power, human or animal. Yet how profound by contrast is the result! A pivoted horizontal wheel, to the hub of which is attached an arm, can be turned by a man or by a bullock. The same wheel, provided with fins, can be spun round by a stream of water with precisely the same effect. Worked by water power, it is a non-stop machine working day and night, summer and winter, so long as the stream flows.

It involves a new principle – the application of natural power (otherwise wasted) to work the machine, thereby relieving both man and his domestic drudge, bringing him leisure and ease.

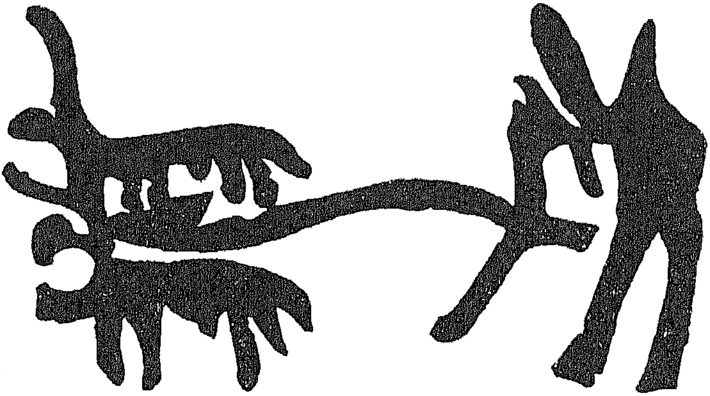
Let us see what work man had to do as culture increased that could not be done by hand, or that he could do quicker – and *needed* to do quicker as the tribe or colony increased its numbers – or with less effort, by using a machine. What, in fact, were his activities?

Settled Man had to:

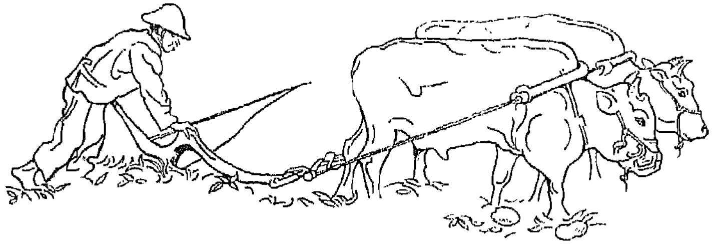
(*a*) Lift and carry weights.
(*b*) Haul logs, stones, or other heavy objects.
(*c*) Fell trees.
(*d*) Dig.
(*e*) Raise water from the river, lake, or well.
(*f*) Husk grain.
(*g*) Grind corn.

It will be noticed that all these chores are directly or indirectly connected with agriculture – clearing land, irrigating crops, preparing grain, building huts – and there can be no doubt that the first machines were agricultural machines. Nor can there be the least doubt that they were made of wood and of roughly hewn stone; if any other raw materials were available when the first machines were being constructed – copper, for example, or lead – it would have been too rare for the purpose of making machines.

Hunting and food-gathering also would long have outlasted the earliest settlements, and the nomadic food-gathering tribes which persist to this day give a fair idea of the kind of chores early Man was faced with. They at least had no self-acting machines which, as already pointed out, could only have been devised by a settled population devoted to agriculture. On the other hand, many agricultural tribes, such as the Chingpaw and others who inhabit the mountains of Burma, do almost all their agricultural work by human labour. It seems strange that even today, all over the world, the great majority of mankind still depend on muscle,



Neolithic cave drawing of a ploughman. Sweden (Aspeberg).



The soil of China is still broken with the wooden plough.

human or animal, for their chief – if not their only – source of power.

In this twentieth century it is certainly an anachronism to see Man pulling rickshas and pushing families around on wheelbarrows, or carrying mandarins in sedan chairs, in the streets of a great city. Yet to speak of a 'machine-age' is to throw everything out of perspective. Every age since civilization was invented has been a machine age – civilization *is* the machine age; but the power machine was no more universally used in the age of wood and stone than the internal combustion engine is universally used today. While there are many things Man cannot do without the aid of the machine, the machine cannot do anything that Man cannot do at all – in other words, what the machine does is only an extension of what Man can do. Man, unaided, using the simplest tool, can crack a pebble, dig a trench, flatten a lump of lead, fell a tree, lift a rock, propel a boat; with a not very intricate machine made chiefly of wood he can even soar. The power machine on the other hand beats a lump of iron to the thinness of tissue paper, digs a canal, pulverises a mountain, cuts down a forest, lifts a hundred-ton tank, drives a battleship through the water or a heavy bomb through the air.

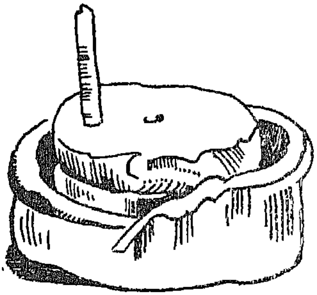
But there are some things which Man can do which no machine, however delicate, can do. It cannot paint a picture, compose a sonata, write a poem – though it can reproduce these works when Man has given them birth. Neither can it plan a policy or administer a province, though it can, under Man's guidance, *calculate* figures with great rapidity. But it can give Man the leisure to do these things, the leisure to think and experiment.

Let us make no mistake about the limitations of the machine, but let us not underrate it either. Man is, in the first place, as we have seen, dependent for power on his own strength. He can lift a weight, drop it, or hurl it; he can carry a load, push it, haul it; he can strike a blow, excavate – and all these things he can do with his hands and muscles

Aborigine of south Australia cutting a tree with an unflaked piece of stone.

alone. Given the simplest stone tools, he can hammer, chip flint, bore and scrape.

Man's physical strength, however, is limited. He can perform only a limited amount of manual labour in a given time. Animals can do much more, although their strength also is limited. But Man, using his brain, can overcome the limitations of muscular strength by devising the machine, and harnessing outside power. The first power machines may have been invented 5000 years ago. The husking and



Old stone quern for grinding grain.

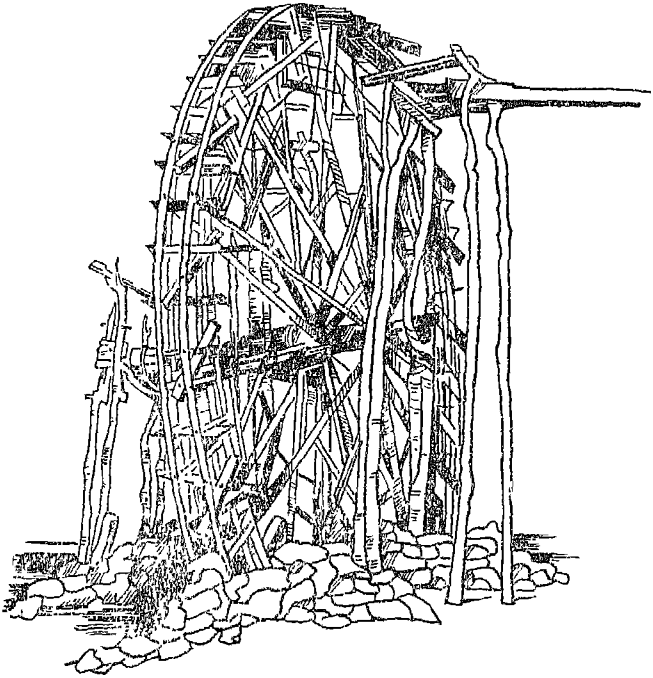
grinding of corn, and the irrigation of crops were probably three of the earliest things Man tried to do with the aid of machinery. The hand quern, in which one circular stone is made to revolve on a fixed stone, the grain being fed through a hole in the upper stone, is well known. Nor is it difficult, given a small head of water, to work such a grindstone with outside power; it is only necessary to attach a horizontal wheel to the axle carrying the grindstone, and to let the stream play on this. (Here of course it is the *lower* stone which revolves while the upper one is fixed.)

Another simple machine commonly met with in North Burma and in Western China, is the automatic water hammer used for husking paddy and other grain. A log of wood about four feet long and well squared up is pivoted near the middle, one end overhanging a stream; this end is hollowed out like a horse trough, and a stream of water directed into it by means of a

The hand-mill for grinding grain is still used in Oriental and Mediterranean countries.

bamboo flume. To the other end is attached a billet of wood like a long mallet head. The mallet head works in a shallow circular hole and is of such a length that when the lever is horizontal the head of the mallet rests on the bottom of the hole, thus supporting the lever. Hence the trough (being horizontal) can hold water. As the flume leads water directly into the trough, that end of the balanced log becomes heavier, and by the time the trough is full it is top-heavy and so tips up – or rather, down. In dipping down, however, it tips out the water, thereby restoring the balance and returning to its original horizontal position, the mallet at the same time dropping with some force into its hole. The hole has been filled about a quarter full of paddy and the heavy mallet plunges into this, husking a certain amount of it. The trough then fills again and the process is repeated and continues as long as the water continues to flow. Man has nothing to do except take out the husked paddy and put in more. Yet in spite of the machine, in hundreds of hill villages the girls husk the paddy every morning and evening, wielding a heavy wooden club held in the middle and lifted vertically, to be thumped into a hollowed tree trunk at the bottom of which the paddy or other grain is placed.

Still more ingenious is the 'Persian wheel'. This is a power machine devised for lifting water from a river into the fields along its banks, and has been in use for thousands of years – and is used in China and other parts of Asia to this day. It consists of a light bamboo frame paddle wheel supported between uprights fixed in the river bed, and kept revolving by the force of the current. Bamboo tubes are fixed diagonally round the circumference, at such an angle that as the wheel revolves they scoop up water from the river and carry it up to the top; as they descend, they tip out their contents into a bamboo gutter suitably raised on trestles, which distributes it to the fields. The diameter of the wheel is, of course, considerably greater than the height of the river bank,



Water wheel (near Lanchow) irrigating a farm some 60 feet above the Yellow River.

and is sometimes as much as twenty or thirty feet. This may have been one of the earliest uses of the wheel, before its advantages for transport on land were perceived. The grindstone is also a potential wheel.

It will be noted that the only materials used in the construction of the power machines described above are wood (or bamboo) and stone, and the only tools required to construct them are an axe, a chipping tool and a borer. Thus with the simplest tools – and some ingenuity – Man was able to build labour-saving machines which put agriculture on a firm basis. So long as he himself had to lift water from the river, turn a grindstone, or pound grain in a wooden mortar, he was wearing himself out. With the invention of the power machine, he began to have leisure. Yet it is clear that the power machines just described could not be invented just anywhere. They depend for their action on fast running streams, and would be useless on flat, dry plains such as those of the Middle East – on the Nile or the Indus deltas, for example, where some of the earliest known civilizations were founded – so we may assume that they were invented elsewhere.

It seems unlikely, therefore, that the power machine has been in use for more than a few thousand years, that it is, in fact, a modern invention. It is particularly appropriate to those parts of the world where food, and hence population, is not abundant. The rich delta lands of the Middle East could support a large population, and where labour was cheap there was no urge to invent labour-saving devices. Civilization rapidly became stereotyped. More dynamic civilizations sprang up in the foothills and in hilly regions, like Greece. Man would not develop an irrigation wheel until irrigation became necessary – that is, until there was something to irrigate – any more than he would invent a quern until he had corn to grind. The fact that these simplest of all power machines are closely connected with agriculture or gardening, suggests that they were invented after the invention of agriculture. They are modern.

Nor is the machine which depends upon outside sources for power necessarily static; the sailing ship, for example, by the power of the wind, can go round the world. But it was not until very recent times that Man built the first land and air locomotive engines, which revolutionized transport. No longer dependent on outside sources of power, these machines developed power from the combustion of fuel fed into the heart of the machine – a great improvement, since it made them far easier to control.

Let us now discuss raw materials, and see what bearing they have on discovery and invention.

CHAPTER XI

RAW MATERIALS – I

I WROTE in Chapter VIII that raw materials have played an important part in the invention of civilization, and at this point it will be convenient to consider their role in the long drama of Man. There is a lot of loose talk about the materialism of modern civilization, especially western civilization. But the steel frame of civilization *is* material; until a solid material basis has been built up, no culture is possible. If there are glaring faults and failures in modern civilization – which few can deny – at least a small pure stream of culture flows from it to irrigate life all over the world.

Civilization had to be *invented*. It was not something which just happened, which was bound to happen sooner or later; nor could it have been invented without recourse to raw materials, first those substances which occur naturally on the Earth's surface, and secondly other substances which can be extracted from them by various means.

The history of civilization, then, is the history of raw materials, and this is as true of eastern as of western civilization, though the former is often pictured as being less materialistic than the latter. What raw materials, then, are necessary to civilization? What is the *minimum* number of raw materials which Man must use before he can hope to lay down even the foundations of civilization, or, to pose the question in another way, at what point in the history of raw materials did civilization begin?

It is necessary to say a few words about these familiar, yet in some ways mysterious, substances which have played such an important part in the Pilgrim's Progress. Man is Man, we can agree – savage Man still, but not beast – when he has the power of speech and the secret of fire; when he uses tools and walks upright, when he goes about in families, or in tribes, stepping on the ground, living in caves or building huts. He was not, we apprehend, civilized Man until he cultivated the soil and possessed domesticated animals and plants. Savage Man, then, needs very little in the way of raw materials. He is sufficiently distinguished from the apes by certain anatomical characters, including jaw, hands and brain; but he is still a long way from civilized Man. If we ask what were the first raw materials he used, the answer will probably be – sticks and stones. It is the use he made of them rather than the choice of substance – function rather than structure – that distinguished his life from that of the apes. If we agree that primitive Man had wood for his cudgel, flint or other stone for his tools, and the skins of wild animals to protect his body from the cold, we shall probably have enumerated all the raw materials that the earliest men – or *some* of the earliest men – made use of. Three seems to be the minimum number.

How did savage Man add to these? How were discoveries of raw materials made? Primary raw materials, like certain forms of power, exist independently of Man. They are the stuff of which the Earth is made; and if Man vanished from the face of the Earth tomorrow, they would continue to be. It seems likely, then, that given the right conditions, Man would sooner or later discover them. But owing to the irregular distribution of most raw materials over the Earth's surface, no man, savage or civilized, whether he inhabited Europe, Asia or Africa, would be acquainted with more than a very few. It was not a knowledge of what raw materials *existed* that Man needed, so much as a knowledge of their possibilities and what use he could put them to.

In the course of his wanderings Man must have found a number of objects which he picked up either because he thought them useful, or pretty, or queer; often they were just something new. Man was – and is – curious. Just as a child today is attracted by the glitter of mica, or the weight of tinstone, or the colour of haematite, so also was primitive Man. One can imagine him picking up deer's antlers, for example – and there must have been many; or the skull of any dead animal, bones, sinews, teeth; land, sea and river shells; or again, seeds, grass and leaves, jungle creepers, which are all in their way raw materials, as are clay, chalk, mud, stones, sand and other kinds of rock.

It is certain, however, that for thousands of years Man in any one region (especially away from the sea shore) must have got along with less than a dozen different raw materials. The number of raw materials which are found free is limited, or at least the number which primitive Man could use is limited. Today we use sand to make cement and glass; clay to make pots; chalk to make quicklime; but to primitive Man these materials were useless. He wanted *tools*. And the great majority of raw materials in use today are complex substances from which other substances are extracted, by some more or less complicated process.

Gold was probably the first metal ever discovered, although it is just possible that iron or tin was discovered even earlier. But gold, though widely distributed, is not found everywhere, nor in vast quantities. No doubt it was found by several different tribes, in widely sundered places, thousands of years before any use was made of it. Nor can it be doubted that primitive Man in different parts of the world discovered, mostly by chance, different raw materials. The earliest known civilizations of the Middle East, founded in hot, dry, flat lands, were founded just there, not because all the raw materials they required occurred there, but because the first requirement of any civilization – agriculture – was developed there and, so far as we can see, could have been developed *only* there. It was trade which provided most of the raw materials which they used.

We still have not answered the original question – what raw materials could primitive Man have possessed? How did he increase their number? That many were found by chance is certain. It is said that petroleum was discovered in the jungles of Assam by an observant hillman who noticed that elephants coming from a certain direction were caked with mud which glistened; it was as though they were glazed. Perhaps no special significance was attached to this fact, and certainly no inference was immediately drawn. But it was regarded as peculiar, and curiosity drove men to follow the elephants to see where they wallowed in such unusual mud holes or streams. The presence of oil may have been known to a few wandering people for centuries before men with sufficient knowledge and experience to draw inferences came along. Or, on the other hand, jungle tribes may have been burning surface oil for centuries, as happened in Upper Burma. Natural gas in oil-producing regions, ignited perhaps by chance, may easily have led early Man to examine the region.

Many a casual find was for long put to no practical use. Early Man must have noticed many unusual substances, such as pyrites, sulphur, mica and other rocks, which are common and widely distributed, yet sufficiently uncommon to have attracted his attention. Such substances may have been known for thousands of years before they were put to any practical use. All his possessions, all his equipment, were plain raw materials, for he knew no process of manufacture, extraction or refining. He observed that clay hardened in the sun and became softened by water, that wood charred in the fire. But what else could he have known! His only tools were of chipped stone. He had no metal, nothing from the limitless harvest of the sea but what he could pick up along the shore – weed, shells, dead fish, coral perhaps.

Obviously he could have no knowledge of minerals which have to be mined, except those which come to the surface in the free state; he lacked the simplest equipment for mining, which is a highly skilled and profoundly technical operation. The oldest deep mining in the world is probably the Chinese method of extracting brine. The only equipment used is bamboo and rope, the 'drill' being a heavy wooden pointed stake which is pulled up and allowed to fall on the same spot again and again. It takes many years to pierce a well deep enough to reach the brine, which may be 2000 feet down. How the Chinese knew that there was brine so far below the surface is a mystery. But this method of mining cannot be more than a few thousand years old and hence comes within the age of civilization. There may conceivably have been still more ancient methods of mining for gold in Central Asia; but it seems much more likely that this was surface

Chipped flint implement, a heavy tool known as a hand axe.

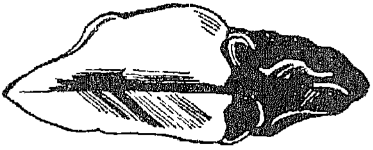
or alluvial gold. Nor does that take us back more than about 10,000 years to late Palaeolithic times.

But many raw materials, particularly metals, were denied to early Man (whether or not they were visible on the surface) owing to his lack of tools and of technique. Thus silver, iron and tin came much later than gold; and though petroleum occurs at the surface, it is generally found in places inaccessible to Man so ill-equipped as was Palaeolithic Man. Iron and tin long remained unknown except in the form of pyrites and tinstone. It was no mere chance that at the beginning of the Christian era only seven metals were in common use. The early metallurgists could extract and work only those metals which occur in the free state and more or less pure. Iron, though perhaps the most widely distributed and most abundant metal in the universe – occurring commonly also outside this Earth, as well as forming the central core of it – is not amongst the earliest known metals, because it rarely occurs on the surface of the Earth as metallic iron. The 'Iron Age' began in Europe about 500 B.C. and cannot have been much older anywhere else.

Copper and even silver were known, or at least were used in the arts, long before iron; and the former at any rate is found as metallic copper. Tin, lead and zinc must have been known when the Iron Age began 2500 years ago. Copper and bronze (an alloy of tin and copper) had already been in use for a thousand years, and gold was known at least a thousand years before that. Thus at the dawn of the Iron Age not less than seven metals were known. All this, however, is written history, and falls well within the age of civilization.

When we speak of the 'Iron Age' or the 'Bronze Age', it does not mean that these metals were universally, or even commonly, used. It is much more probable that few people used them, and in few places. The vast majority of men still lived in the Stone Age. So it is today, in the age of steel and concrete. Only a small minority of the inhabitants of the world use, or benefit from (except indirectly), these substances, although the use of the former at least is spreading fast.

Apart from its inherent interest, this historical survey of raw materials is of the utmost importance, because every forward step, every stage of civilization, is ushered in by the discovery of new raw materials and an understanding of their possibilities. It is inconceivable that any advance was made before the discovery of the raw materials which would make such an advance practicable. Before that it existed, if at all, only as a dream. In our own times Jules Verne and H. G. Wells wrote their stories of the shape of things to come, but in terms of *known* raw materials and familiar technique.



Knife-dagger, consisting of a flake of stone with a grip of hard gum (central Australia).

It would be interesting to know what raw materials were in general use at any given period in the history of Man, and how widely diffused they were over the inhabited world. Raw materials preceded invention; and we may safely say that when fire was discovered, sub-man – whether in South Africa or in eastern Asia, or anywhere else – had no more than the minimum number of raw materials. Then, over a period measured in tens of thousands of years, came the gradual evolution of Man from sub-man – we know not where. What raw materials, if any, had been added to the store during those rough ages?

Somewhere about that time simple machines were being invented to irrigate crops and to grind corn, to move heavy weights and to carry loads, as a substitute for man-power. Surely such a step would need a large increase in the number of raw materials in use? And so, increasingly, down to the complex civilization of the present day.

CHAPTER XII

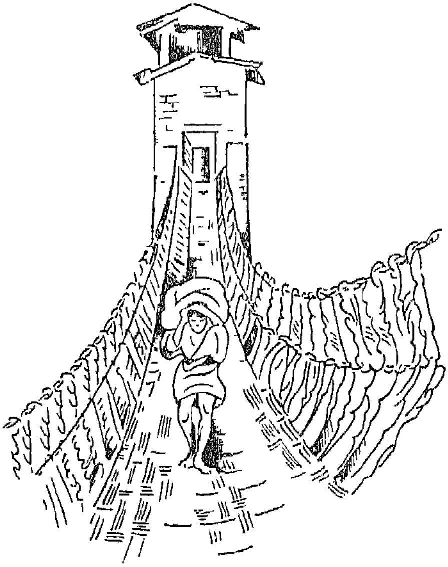
RAW MATERIALS–II

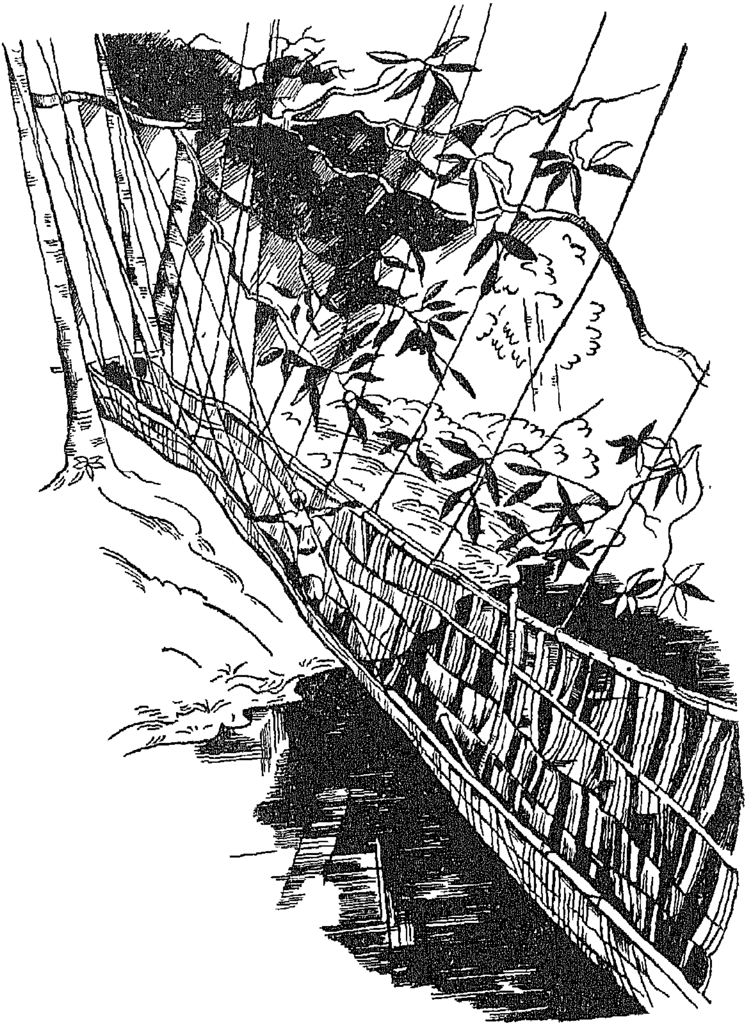
THE relationship between raw materials and progress in certain respects is clear. As pointed out in the last chapter, nobody could invent anything until the materials for making it had been discovered. It is, however, equally true that until invention and discovery had progressed, many simple raw materials remained unknown. Thus raw materials on the one hand, invention and discovery on the other, acted and reacted on one another.

But this does not tell us very much, for it is an undoubted fact that many quite complicated things can be done with a very simple and limited range of raw materials. To make fire, to construct a simple machine, to domesticate animals and plants, calls for the minimum of raw materials. Even the arts of writing, of pottery and of weaving need only a few more. This fact alone makes it obvious that most of the steps which revolutionized civilization were taken in prehistoric times, and that most modern inventions are simply improvements on earlier inventions and discoveries.

While it is true that Man could not make anything until he had at his command the appropriate raw materials, it would be rash to say that it could not be done at all by primitive Man for lack of what appear to be the appropriate materials, without inquiring very closely into the matter. For example, it is tempting to think that it would be impossible to build a suspension bridge before the invention of steel; but it would be quite incorrect. In western China and other parts of south-east Asia there are excellent examples of suspension bridges slung on iron chains supported by masonry towers; and these span big rivers like the Mekong and the Salween. Such iron-chain suspension bridges antedate the elaborate steel structures of Europe by several centuries at least. But obviously such bridges cannot carry modern traffic.

However, the principle of the suspension bridge is older than that. In the hill jungles of Assam and Burma the tribesmen construct excellent suspension bridges out of such simple materials as jungle creepers and cane or rattan, which is a species of climbing palm, with long, thin, immensely strong and flexible stems. Even the mighty Dihang, the main stream of the Brahmaputra (which is the name given to Assam's great river when it debouches on to the plains) is


Suspension bridge slung on iron chains.



Cane suspension bridge.

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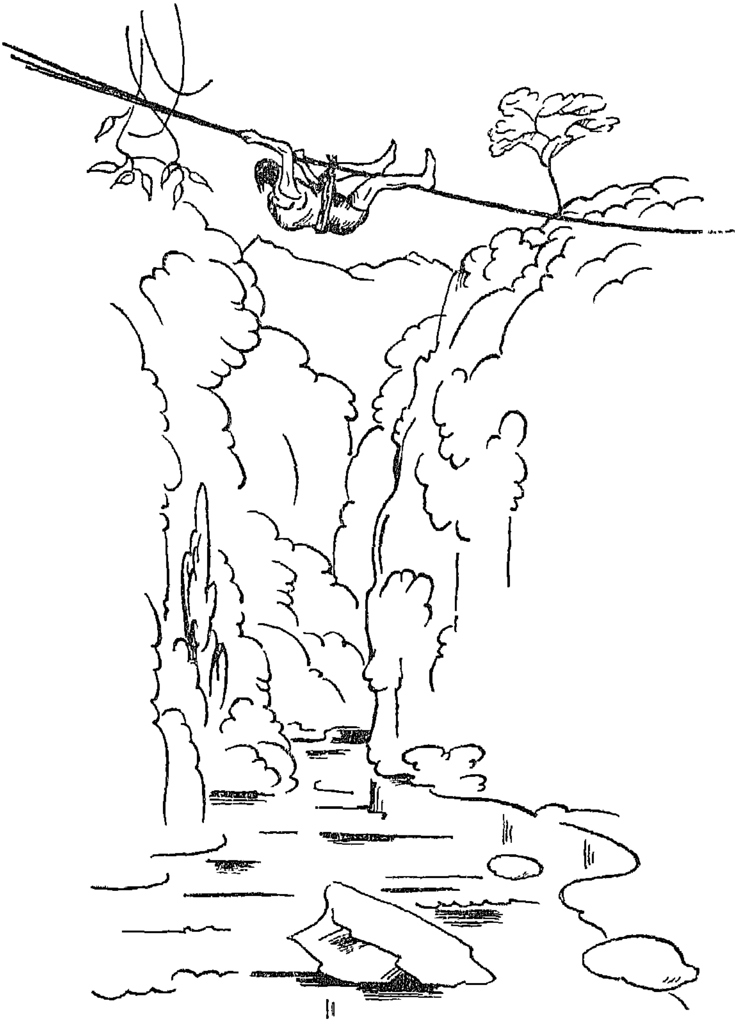
spanned by a cane suspension bridge of great length. I shall not easily forget the qualms I felt when first I crossed this spider's web, suspended more than fifty feet above the swift-running river. This astonishing bridge was constructed by the Abor tribe, and one may hazard that the Abors, or some other hill tribe, have been constructing similar bridges for centuries. It is not likely to have been based on the iron-chain bridge. The hill tribes of this part of the world, though civilized, are not highly cultured, and get along with few raw materials, most of which are used raw. The only metal in common use is iron, although through barter and trade they are acquainted with gold, silver, copper, lead and nowadays even aluminium cooking-pots. Their huts are built of timber and bamboo, thatched with grass or palm leaf. Their scanty clothing is of cotton woven on a hand loom. They use flint and steel, the cross-bow or long bow, dyes, poisons. Probably the whole range of raw materials habitually used by them does not reach fifty, and not even the majority of these are of local occurrence or manufacture.

The inference seems to be that a high degree of civilization is attainable on a small selection of raw materials. For these tribes possess a considerable variety of domesticated animals and plants, have some knowledge of the power machine, and are organized on a tribal basis, with complicated relationships within each tribe. If the above inference is correct, what becomes of our thesis that civilization is built on raw materials, and, by implication, the richer the civilization, the more raw material will be used?

The fallacy lies in assuming that these tribes built up their civilization with the aid of the raw materials they now possess. On the contrary, it is pretty safe to assume that every tribe here is a chip of an older block which broke away from the main body and painfully adapted itself to



Three strands of cane. Simple rope bridge of north Burma.

austerity in the jungle, leaving a good deal of its culture behind.

An authority has stated that to conduct a modern war, some 10,000 different raw materials are required; and one can easily believe it. All these have their uses in peace also, if in different proportions. The bearing of this on our story is simply to show what raw materials were – or at least might have been – available, when the next step forward was taken, and what, if any, raw materials were necessary before the next forward step *could* be taken. Certain substances are essential to achieve certain ends, but as indicated above, one must not hastily conclude that there are no substitutes for what at first sight appear essential materials. Jungle canes will suspend a bridge capable of supporting a man, and tensile steel is merely a stronger substitute, capable of supporting a tank. Conversely, if we know what raw materials were in use at a given time in a given place, we might be able to gauge the level of culture attained.

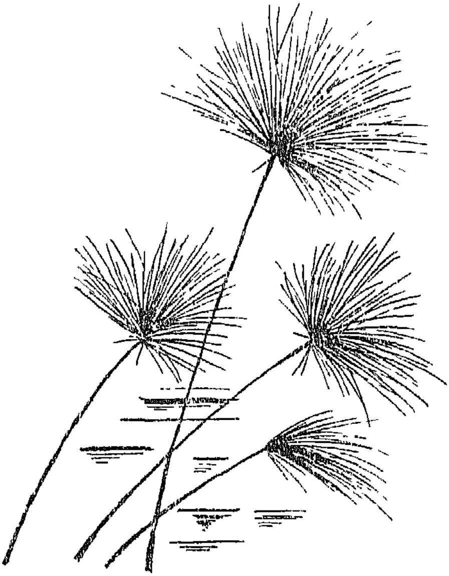
Without the aid of metals Man could still have discovered that the Earth is round, and invented writing; but he could never have discovered the Poles, or invented the internal combustion engine. That the discovery of metals had a great influence on mankind is obvious. It led to the invention of modern firearms. It might reasonably be claimed that the discovery of metal and its uses had a greater effect on the world than the invention of writing; and that the substitution first of bronze, then of iron, for stone, was a major advance in civilization. We are, of course, still in the Metal Age, now in its fifth or sixth millennium, and never before was there a time when so much iron and steel was used. But men killed each other with stones many thousands of years before iron was thought of, and just as effectively. If more people are killed by metal nowadays, that is mainly because there are more people to kill.

But firearms can be made of other materials than metal. The Chinese guns, in some of their wars, were made of leather, just as shields and personal armour have been made of leather, which is an adequate protection against lance and knife, if not against bullets. Chinese leather cannon produced decisive results against the Nepalese some 250 years ago, when a battle was fought between them on the roof of the world. These skin guns not only inspired terror, but did terrific execution – though it was the Chinese troops they mowed down. At a critical moment in the battle, the Chinese, apparently beaten, retreated, and the retreat threatened to become a rout; whereupon the Chinese General, calm in any crisis, began firing off his leather artillery, doubtless kept in reserve for just such an emergency. As each gun burst it played havoc with the fleeing Chinese, who turned again, in order to put themselves at the safer muzzle end of the ordnance. Hounded on by their General and by their exploding guns, they fell upon the Gurkhas and drove them from the hard-fought field.

Undoubtedly the discovery of metal, and the invention of the attendant techniques of smelting and metallurgy in all its forms, made possible navigation, the conquest of large sections of the Earth, both land and sea, and much else besides, as metal was substituted for wood. But it does not appear to have altered the course of civilization so profoundly as, say, the domestication of animals, the recognition of power, or the invention of writing.

The mere discovery of new raw materials did not lead immediately to new inventions. Many raw materials, especially minerals, must have been regarded for centuries as merely curious. There was no research into the properties of matter.

On the other hand, even the recognition of natural power apart from life – the strength of the wind, of the rushing stream – did not depend upon the discovery of raw materials. It was the *application* of that power to human use which might – and generally did – have to await the discovery of some new substance. It was human ingenuity and logic which enabled Man to advance from discovery to discovery.



The earliest paper was made from the pith of the Papyrus plant.

As a concrete example of the action and reaction of ideas and things upon one another, let us consider the invention of writing. The earliest written, painted or carved signs for ideas were being shaped six or seven thousand years ago, and it is reasonable to suppose that for some centuries before that Man was groping his way towards some system of recorded words, that is to say, a written language. Now the earliest known writing is the cuneiform script scratched on soft clay tablets and preserved by the simple process of drying the clay in the sun, and later of baking it in a fire. The script was scratched with a wedge-shaped stylus, probably made of metal – copper was used in Chaldaea between 5000 B.C. and 4000 B.C. But it might equally well have been made of hard wood, of bone, of shell, or even of chipped stone.

Later, scripts were written or drawn on Papyrus, which is the pith of a sedge growing in the swamps of the Nile. Papyrus was the first paper. Still later, in the eastern tropics, letters were scratched on the smooth shiny surface of palm leaf, likewise with a sharp-pointed instrument; or painted on rice paper, silk, or other material of vegetable origin. In the West again, down to comparatively recent times, parchment – the skin of an animal – was used, and *illuminated* scripts were introduced, decorated with gold leaf.

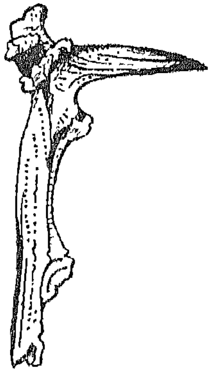
Thus the earliest and simplest form of writing so far known, namely cuneiform, required only two kinds of raw material for its production – clay and some hard substance (stone, bone or metal), neither of which needed any further raw materials in their preparation, for they were used raw.

One supposes that these materials had been known for some time before writing emerged as an accomplished fact. But to write Chinese hieroglyphs you also need at least three raw materials different from those just mentioned – paper, which is of vegetable origin; ink, which may be mineral (lamp black) or vegetable; and a brush, probably of animal hair and bamboo. The paper itself, however, is manufactured. Writing on vellum makes a still greater call on raw materials. Thus as writing expands, new raw materials are called for, or as new raw materials are discovered, culture becomes more diverse.

Again, the first simple machines, such as the lever and the wedge, and even the wheel, were made entirely of wood. No metal is needed to make a wheel, and certainly none was available when the first wheels were being made. Solid discs of wood, turning squeakily on an axle, are in use today, as in the Burmese Shan States, while wooden water wheels, both horizontal and vertical, are a commonplace in south-east Asia. Sugar presses with interlocking gears which turn the rollers in opposite directions, handlooms, cantilever bridges, cart wheels, barrows, even door bolts, besides many domestic articles and agricultural machines, not to mention houses, are made entirely of wood.

But even such almost universal materials as wood, stone and leather, require work to be done on them before they can be of much use to Man. Raw materials are not of much use until a technique for making them serviceable has been developed. Civilization is built up not only on raw materials, but on techniques. Primitive Man had at his disposal what every animal has to this day – that is to say, water and food, air to breathe, and perhaps a certain minimum of salt. Like most animals, he probably had to spend much of his time looking for food, if not water – the raw materials of life from which modern chemists extract vitamins and other essential components. Very slowly he added to these barest necessities, and still more slowly developed suitable techniques with regard to them. Yet in 'Dolmen' times (7000-5000 B.C.) already a technique for mining flints with deerhorn picks had been brought to a high state of efficiency in Britain. This was a great advance, though not so great as was the idea that metal might replace stone.

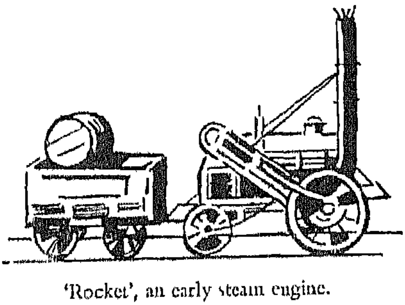
A wooden flume, gouged from a tree trunk with a stone tool, or with fire, might serve to irrigate a field. A wooden wheel, pivoted on an axle and set revolving by means of a



Deerhorn pick. Britain, 7000-5000 B.C.

stream flowing against its fin-like spokes, thereby turning a round flat stone impaled on the axle, the latter turning upon a fixed stone, is all that is required to grind corn. But these ideas – as opposed to the raw materials used – are modern. No one invents irrigation until there is a crop which needs it. It is not until we come to mechanical power and the conversion of heat into energy, that a variety of new raw materials – notably metals, lubricating oils and fuels – become necessary. Even so, it is well to remember that the earliest steam engines, including locomotives like 'Rocket' and 'Puffing Billy', were constructed almost entirely of iron. Steam power on a practical scale is less than 250 years old, and it could not have been invented until the number of raw materials in use had increased greatly. Even so, compared with the number in use today, it was still small.

Sub-man or ape-man must have used at least the minimum two or three raw materials during the second or third interglacial period, half a million or more years ago. He may not have worn skins, and perhaps did not need to. He possessed fire, but had made no further advance. Tens of thousands of years must have passed before he



'Rocket', an early steam engine.

added anything to his armoury of sticks and stones.

By the time animals had been domesticated and grain plants cultivated, by the time writing had been invented and simple machines were in use, civilizations were growing up in the Middle East. Taking the whole inhabited world of six or seven millennia ago, Man may have had knowledge of two hundred or more raw materials. Iron, lead, tin, zinc, copper, gold and silver were all worked in prehistoric or early historic times. Clay for pots, fibres for weaving, gems – precious, semi-precious and non-precious – for personal adornment, pigments, silica for glass, skins, plumes and other animal derivatives, were all known in the city states of the Middle East, around that tideless sea which was the cradle of coastwise trade, or close to the Persian Gulf or the Red Sea. The people, too, of those progressive communities had many of the arts, advanced to an astonishing degree in technique.

Today we use in our factories and in the arts more than 8000 different raw materials of animal, vegetable or mineral origin. They range from primary raw materials, such as foodstuffs, to minerals like diatom earth, petroleum, platinum and diamond; animal products like silk, camel hair, leather, whale oil, ivory and musk; and vegetable products like bark (for the extraction of tannin and quinine), tea, coffee, cocoa, cotton, flax, oils, rubber, copra (for the manufacture of soap) and timber.

The average city worker in the West who lives in the suburbs and spends the greater part of his life in an office in a factory-built world, hardly stops to ask himself how many raw materials go to the making of it; still less where they come from, what techniques are used to extract or purify them, or how long they have been known to Man. Much of his external world is, perhaps, built up of ferro-concrete and steel, or at any rate of brick and stone; and all these include a number of substances in their make-up, each of which must be separately extracted. But besides these, literally hundreds of raw materials, apart from food, have helped to make his world comfortable and enabled him to leave the prime necessities of getting food, water, fire, clothing and shelter to others, though the provision of food is directly the concern of far more than half the total population of the world.

Let us take a quick glance at a few of the western city worker's daily needs, and inquire what raw materials are required to supply them. The soap, tooth-paste, hair oils, scents and other beauty preparations that he and his wife use are mostly of vegetable origin. The clothes they wear, the brushes, bedding, furniture, upholstery, are of vegetable and animal origin. Inside the house and largely invisible, a score of metals, such as iron and steel, zinc, lead, manganese, mercury, chromium, silver, aluminium, nickel, copper and tin are used, and our couple's 'personal effects' are likely to include still others; all these metals, part of the equipment of the house, contribute to their comfort and convenience, save time and trouble, or help to amuse and educate them and keep them in good health. Finally, the many decorations, personal and otherwise, and preservatives, trinkets, ornaments, paints and distempers, black lead for the stove and blacking for boots, soda for washing, and a dozen other things – games, books, toys, and the rest – all mean more and more raw materials, dug out of the earth, grown in plantations, bred on farms, hauled out of the sea or the air or the jungle (some of them from Great Britain, but more from distant lands), and worked up in factories by various processes – processes which in turn need other raw materials for their action.

Numerous as are the raw materials used in modern industry, however, the western nations are far from knowing, or at any rate using, all that may be known in other parts of the world. Visit any city in the deep interior of China or in the eastern tropics, and in the little drug stores and miscellaneous junk shops you will find set out for sale animal and vegetable products – extracts of cuttle fish, seeds, roots, fruits, twigs, as well as minerals and powders – of which the West knows little or nothing. Amongst the mountain tribes of Assam, Burma, Malaya, New Guinea and many other parts of the world, medicines, potions, charms and other concoctions unknown to the European will be found.

Raw materials, going from their place of origin to the workshops of the world, form a large part of international trade, and it seems ironical that western civilization, as we know it, may conceivably stand or fall by the movement of a single raw material – uranium ore – of which, so far as we know at present, there is not much on this Earth, and none in Britain. Did a comparable situation ever arise before? Possibly, with the introduction of bronze weapons in the Middle East, some four or five thousand years ago. Happily, civilization survived.

Each step forward, then, was made possible by the introduction of new raw materials, though it is unlikely that primitive Man consciously sought them. Neither does modern Man. He seeks particular raw materials which he already knows exist – gold, oil, wolfram – but entirely *new* raw materials are almost always found by chance, while he is actually searching for something else. What modern man does is to analyse with increasing perspicacity the complex raw materials he already possesses – coal and petroleum are good examples – to improve, cheapen and speed up the methods by which simpler substances are extracted from complex ones, or by which complex substances are synthesized, atom by atom, in the chemist's laboratory; and to seek new sources of raw material for a given product. The discovery of entirely new raw materials is, generally speaking, fortuitous, though there is at least one exception to this; namely, when the search for a suspected missing chemical element to fit into a theoretical framework is sometimes deliberately undertaken. It was the deliberate – and successful – search for such an element by the Curies that led to the famous discovery of radium.

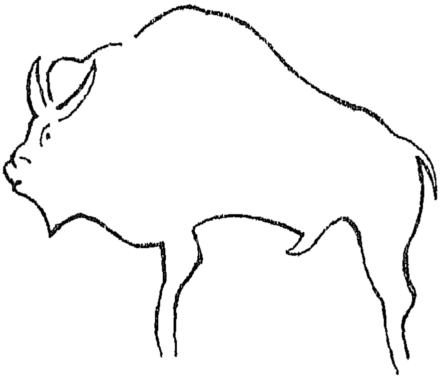
Owing to poverty of raw materials, and of technique, primitive Man was equipped to occupy only a few chosen lands, all more or less of a pattern; until he found those spots, he remained a wanderer. Modern Man, with the great range of raw materials in his possession, or with the things manufactured from them, is able so to increase his command of nature, that he can occupy lands hitherto regarded as uninhabitable. It would have been impossible to discover the Poles before the twentieth century, or to cross the Pacific in the twelfth century, though there were men bold enough to try.

With all this it is sad to reflect that the more men are knit together by improvements in transport and communications, the more they are able to meet and exchange ideas – the less do they find to agree about. That is not the fault of raw materials, inventions, or discoveries, but of Man himself.

CHAPTER XIII

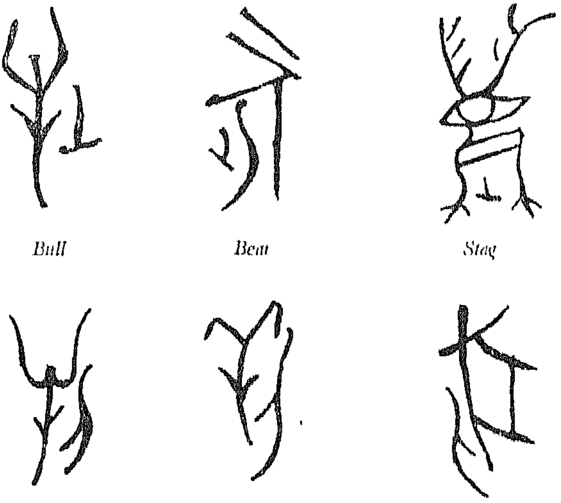
THE INVENTION OF WRITING

MAN could draw before he could write. In fact, the earliest writing *is* drawing. Thousands of years before the invention of the alphabet, long, even, before any system of hieroglyphs was devised, uncivilized Man was drawing on the walls of caves in which he lived, with a wealth of feeling, an almost religious fervour for line. There is tremendous power in some of the earliest cave drawings of animals, such as bison, in Europe, and of men and ostriches in Africa; the beasts are *alive*. One would suspect a sound knowledge of anatomy on the part of the artist. As he certainly had never studied anatomy, one begins to wonder whether a detailed knowledge of bones, sinews and muscles, their names and relationship, is so essential to the artist as the art masters would have us believe. Not that the pictures by



Bison. Palaeolithic cave drawing (Spain).

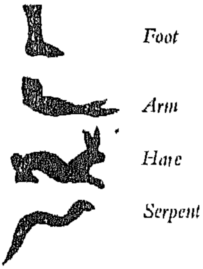
certain modern artists of people meant to be human suggest any profound – or even superficial – anatomical insight on their part – rather the reverse, in fact; but then, these vile modern caricatures, unlike the masterpieces of the cave dwellers, are to most of us anything but alive. Be that as it may, the first writing was, naturally, picture writing, as practised in Egypt 4000 years ago, and in China and Japan today. The picture of an object – 'things that you can touch and see' – presented no difficulty other than the difficulty, which came later, of simplification or condensation, and arrangement. There were at first not many objects to depict; man, animals, trees and grass, the heavenly bodies, rivers, hills, plains and so forth. Ideas, qualities, emotions – these



2000 B.C. Chinese picture writing, showing standard symbols for male (above) and female (below).

were not so easy; but there were not many ideas yet. Brief messages were sent – a string of pictures. As time went on new pictures were added to represent new objects. A *system* of picture writing grew up.

The beginning of writing marks the beginning of history, and indeed of learning. Though he may not have realized it at the time, Man had taken another firm step forward towards the light. Writing was not a mere convenience; it was revolutionary. It crystallized thought, captured the fleeting idea. With the invention of writing and of paper – which, if less durable than the clay tablet was at any rate more easily dispersed – began the amassing of that vast store of knowledge which is our heritage today, and to which every generation – after correcting its forebears – adds its mite. A new kind of education was invented. One would expect that when writing was a difficult art and printing was still a long way off, only worthwhile events and observations were recorded. On the contrary. The earliest writing consists mainly of dull genealogical records of kings and their triumphs.



Egyptian Hieroglyphs.

After picture writing came the alphabet, with symbols to represent sounds, and sounds to represent ideas or objects. This was an immense improvement, but still only an improvement. The first alphabet probably originated in the Middle East, whence it gradually spread over the Mediterranean and eastwards to India, amongst peoples who, though they could not write, could, presumably, draw. It replaced hieroglyphs in the Mediterranean civilization, and from India it spread to Burma and to Siam. Much later the Arabs took their alphabet to Malaya.

Meanwhile, the Chinese ideograph persisted in splendid isolation, and spread over a large part of eastern Asia, which was cut off from the West by mountains and deserts. When one comes to think of it, it is astonishing that a whole system of picture writing, in which thousands of objects are depicted, each by a combination of two or more strokes, should ever have been developed; but it is still more astonishing that a system of picture writing should not only have survived into the twentieth century, but should still be the means of expressing the ideas of one fifth of the entire human race. For there is no denying that the pictograph system of writing is too slow and cumbersome in the modern world of hustle, bustle and grab. It is definitely outmoded; it cannot be adapted to the typewriter, and unless it is radically simplified it is difficult to see how it can survive. Whatever virtue it possesses – and admittedly it had a training value in the control of the hands and in co-ordination of hand and brain far in advance of its time – is equally possessed today by other less exacting, and perhaps more useful, studies. The survival of a pictograph script serves to show the extraordinary isolation of the Mongolian peoples, and the truth, so aptly expressed by Kipling, that 'East is East and West is West, and never the twain shall meet'.

Curiously enough, a system of hieroglyphs superficially not unlike Egyptian picture writing, that is of recognizable forms, such as birds, men, buildings, has survived to this day amongst the Moso, a mountain tribe found in western China.

It is difficult to foresee a time when written Chinese – the script of some five hundred millions of mankind – will be as dead as, say, cuneiform. It is equally difficult to see how it can survive in a competitive world with the emphasis on material prosperity. In this age it is an anachronism. If another Dark Age were to overwhelm not only Europe but the whole civilized world for several centuries, it would probably flourish underground; otherwise it seems doomed to go the way of other picture writings. And this is the more likely when we consider how comparatively few of the five or six hundred millions who use some form of Chinese script – the Chinese, Japanese, Koreans, Manchus, Annamites – can read or write. On the other hand, while Mediterranean hieroglyphs have been dead and buried for 3000 years, even at the height of their prosperity they did not spread far from their source, while Chinese ideographs spread all over the Far East. Westwards, however, they finally came up against the ramparts of the Tibetan plateau and the deserts of Central Asia; hence the sparsely populated regions further west drew their inspiration more from India and the Middle East. It is curious that the one branch of the Mongolian race which adopted and adapted an alphabet from India – the Tibetans – should be the least sophisticated of all. But the simplicity of the Tibetan people is really the simplicity, not to say austerity, of a semi-nomadic mountain people isolated by geographical barriers. They are a people who live under the crushing spell of a religious slogan, the meaning of which is generally unknown, but whose efficacy is never questioned.

Malaya, at the time the Chinese ideographs were developing, was a vacuum, and here too it was not Chinese, but Indo-Aryan writing from south of the Hindi Kush, which eventually flowed into it. In proportion to the size and importance of China in the ancient world, the Chinese language did not spread so far as one might have expected; but this, as we have seen, was mainly due to geographical barriers.

Although only a small minority of Chinese, even today, can read and write their own language, it would be rash to conclude from this fact alone that the Chinese ideographs will follow the Egyptian hieroglyphs into the limbo of forgotten things. In China, as in Tibet, the most ignorant peasant reveres the written word, looks upon it as something almost sacred, a gift from the gods. Millions of Chinese who cannot read their own language, let alone write it, venerate every scrap of paper on which the mystic symbols appear. They are proud of their ancient culture and all that it has accomplished in the 4000 years of its existence – language, art, writing, social organization and government. But having been isolated from a large part of the world for so long, and for centuries coming into contact only with less highly organized, less cultured peoples whom they looked upon as barbarians, they have never acquired a sense of proportion – of tolerance. For this reason they have always greatly overrated their accomplishments which, remarkable though they be, are not unique. The West, on the other hand, underrates them. But this is by the way. Here we are concerned with broader issues than the survival or decay of one particular script.

It is because the discovery of fire and the domestication of the first animals and plants took place before the invention of writing, that we know so little about them. Gardening, agriculture, herding, are prehistoric inventions of which we have not even a traditional record. The pictures which Stone Age Man drew on the walls of caves many thousands of years ago may tell the story of the chase, or may tell us what animals were hunted, domesticated or eaten. Or they may be the result of Man's urge to express himself, or have been connected with magic. At this distance of time it is not possible to say for certain. What they do not and cannot tell us, is how early Man lived and thought.

With the written word history begins, and can be checked by material evidence dug out of the grave.

For the last 6000 or 7000 years we find here and there, particularly in the eastern Mediterranean, written records. Much that happened was never recorded, and what was recorded was, for the most part, trivial, at least to us. Nevertheless, whatever was written helps to throw a spark of light on the past. Much, of course, has been lost, although baked clay tablets are less perishable than paper, or even than papyrus, palm leaf or silk, all of which have been used as writing material. Even animal skin – parchment – is not imperishable. However, the preservation of written records depends more on the climate than on the material. Probably we know more about Babylon in 5000 B.C. than we do about Burma in 1000 B.C. We know something of the civilized world of 6000 years ago, thanks to the patient work of archaeologists; but almost nothing of the far larger *uncivilized* world of 600 years ago. Like the whole world before the invention of writing, the uncivilized world of 100 B.C. or of A.D. 500 belongs to prehistory. What did the Elizabethans know of Australia? What do *we* know about it before the age of Elizabeth? A thousand years ago, Australia, New Zealand, Africa south of the Equator, Madagascar, the Polar regions, and much of America and tropical Asia, lay beyond the horizon of human knowledge. Such places had no real existence. Then, indeed, one half of the world did not know how the other half lived – or even that it lived at all! Much of the life of these places we can, no doubt, reconstruct in the light of our present knowledge of them; for uncivilized Man – if he inhabited such places at all – played a very minor part over so brief a period as a thousand years. Yet we would be glad to know more. Nor have all the documents and inscriptions been deciphered, interpreted, collated and compared. New ones are continually being discovered, old ones re-interpreted in the brighter light of increased knowledge.

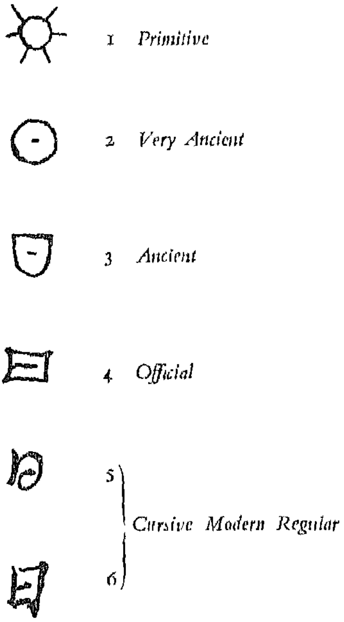
The precise origin of writing and how it was invented is still very obscure. It was almost certainly invented several times as the need for it became ever more urgent. Yet it seems never to have been invented in the New World. It spread, too, by diffusion from each centre of origin, fast or slowly according to the amount of trade and ease of communication. In the eastern Mediterranean it spread quickly and widely because here communications, both by sea and land, were comparatively easy. It may have originated amongst craftsmen who wished to stamp a personal or regional 'chop' on their wares, like the hall mark on English silver and the 'chops' on Chinese porcelain. Or possibly the priest caste had a monopoly of symbols conveying esoteric meanings. Kings evidently had a desire to tell posterity their names and victories, as we read in the Old Testament. No doubt the gradual development of writing took place over several centuries, which in a brief essay like this we must leap lightly over.

Compared with the age of Man, writing is a very modern invention, and still a very imperfect one. Even the alphabet, though a great advance on hieroglyphs, is an imprecise instrument, for the reason that the same combinations of letters can have many different sounds, and therefore meanings (as we all know to our cost). How inexact are the meanings of words is proved every day. Plans, treaties, agreements, drawn up with the greatest care by intelligent men after days of conference, are committed to writing. One would suppose that they expressed ideas in which there was no room for ambiguity. Yet what happens? Another party immediately asks for 'clarification' of almost every item, at least in politics. Does not this imply that the written word is more imprecise than the spoken word, since in conference agreement was reached? In scientific literature this happens less often; but here precise symbols of mathematical exactitude rather than words, and pictures of geometrical design (plans), are a normal procedure.

Clearly, in politics the same words and expressions appear to mean different things to different people. Writing is no more a precise tool for conveying thought than is speech itself. In fact, it *can* be no more precise; written words can only be as free from ambiguity as are the thought they represent. In practice they are less so.

If symbols – combinations of letters – are used to represent sounds, the same symbols should always represent the same sounds, and the same sounds the same ideas. No modern alphabet even approaches this ideal; perhaps the modern American spelling of English comes nearest to it. Tibetan script, though very beautiful, must be reckoned one of the least successful uses of letters – it is the exception for a word to be pronounced as spelt – and the large Tamil alphabet of South India is a peculiarly primitive and clumsy tool.

Another race which has adopted an alien script late in its career is the Malay. Here, again the ill-assorted marriage of the written to the spoken word has led to divorce; the twain are not one flesh, but two. Scripts, of course, pass from hand to hand; they have done so from the beginning, like any other item of culture. No one supposes that the modern races, or at any rate the modern nations, invented the scripts they claim as their own. But it assuredly takes a long time for a native tongue to adapt itself to an alien script – unless it is the script which adapts itself to the language as spoken. The spoken and the written word must act and react upon one another for centuries before they can be welded into an efficient vehicle for the conveyance of thought. The babel of tongues far surpasses the tally of scripts, and a single alphabet has, with slight modifications, to do duty for many tongues. But unless the choice of script for a given tongue is a happy one, the written and spoken languages tend to part company. True, written and spoken Chinese are almost two different languages, and the Chinese script, though it has changed its form more than once, is several thousand years old. But that is another matter altogether. We are speaking here of the choice of an alphabetic script to represent the sounds of a given language. In fact, there is no choice. Ever since writing was invented scripts have been imposed on the vanquished by the victors, as Arabic on the Malays. A few races may have acquired their scripts more peacefully, but the results have not been noticeably better. Can it be that there is a sort of Gresham's Law of alphabets, whereby bad scripts triumph over good ones and drive them out?



Chinese signs for 'sun' showing changes in form over a period of 3000 years (after Professor Cheng An-chih).

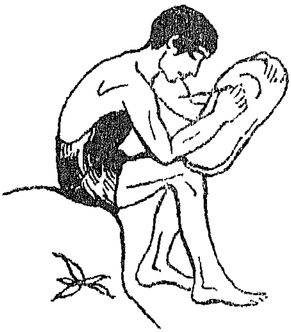
Language is, of course, subject to a gradual evolution, a settling down; and this applies both to the written and to the spoken word. Chaucer's English is not Winston Churchill's; but evolution proceeds from the simple to the complex –

which may account for some queer modern spellings! The tendency nowadays is all towards simplification, and it is noteworthy that the only scripts invented during the last few thousand years are those comprehensively known as 'shorthands'. It is by no means impossible that in the next few hundred years some form of shorthand will replace all languages written in Roman. Just as hieroglyphs, in the course of centuries, gave place to alphabetic scripts, so in due course may the latter give place to the hooks and i's of phonetic scripts. But this still will be an improvement, not a fresh step forward into the unknown.

Spellings which are not pronounced as spelt – an arbitrary value having been pinned to each letter or combination of letters – are really not much better than hieroglyphs; that is to say, combinations of strokes representing ideas rather than sounds. Perhaps it is the very imperfection of written words to express our ideas that lies behind the almost unconscious tendency to return to picture writing, a tendency strongly encouraged by the cinematograph. Newspapers nowadays (especially those designed to appeal to the masses) tell the news in pictures. More and more daily, weekly and monthly publications consist mainly of pictures which 'speak for themselves'.

So the wheel has turned full circle, and we are back to cave man and his murals. As a means of illustrating difficult points, pictures and diagrams – which are symbols – are always preferable to words. Even if one does glance incuriously at the captions of news pictures, it is the *pictures* which stick in the memory. Propaganda by picture and poster is far more effective than propaganda by words. Even slogans quickly lose their edge unless wedded to an effective poster.

Writing developed in each region along the lines dictated by the available material. In China both the ideographs themselves and the silk on which the first writing was probably done made the use of the brush inevitable. Papyrus grows on the banks of the Nile, where the Egyptians learnt to make paper. It is absent from the Tigris valley, and the Babylonians learnt to write on clay, using a metal style. Clay tablets are easily sun-dried in the hot, dry climate of Mesopotamia. In Burma, much later, palm leaf took the place of paper, and its hard, smooth surface necessitated the use of a metal point which could not but make curved strokes, so that inevitably the Burmese alphabet became all 'O's and 'U's.


In Mesopotamia man learnt to write on clay tablets.

The art of making coarse paper from crushed vegetable fibre (on which one can paint words or pictograms with a brush, as is done in China, Tibet and many other countries today) is more recent, but still primitive. In none of these examples is the paper-yielding plant cultivated, and often it is widely scattered – for example, a species of Daphne in Tibet. In the modern paper pulp industry, the source of paper – conifer timber – grows naturally in pure stands on a vast scale, which is as though it were cultivated. Can the fact that no indigenous writing ever developed on the South American continent be attributed to lack of essential raw materials, or to their non-discovery?

With the invention of writing, Man may be said to have completed the invention of civilization itself.

One notes with dismay the modern tendency to slovenly penmanship amongst people who enjoy universal popular education. Those who never learn to write a curved script, such as Greek, clearly, never learn to write Roman legibly at all. Not that Greek is essential to good penmanship; Burmese would do equally well, perhaps better. The firm foundation for good penmanship is pothooks and more pothooks. The typewriter must also share the blame for this rapid deterioration in the standard of penmanship. Nor is bad penmanship peculiar to the West. Cursive Chinese, as written by many merchants who do not employ scriveners, is often illegible to anyone but the writer.

What, then, has the invention of writing done for Man? It is hardly too much to say that, in spite of its imperfections, writing is the cement which holds nations – and civilizations – together. During the 7000 years of its existence it has accomplished much, although even today the majority of mankind can neither read nor write!

Without speech an animal can know nothing beyond its own immediate experience. It is not even self-conscious. Without writing, experience can only build up in the form of tradition and instinct. Perhaps its greatest contribution to human advancement has been to catch and fix the fleeting thought of genius, that swift, elusive, illuminating *flash* which comes and goes like the lightning flash. What would we know of the Bible, of Homer, of Shakespeare's immortal plays – what would the authors themselves know of them – if speech had been handed down from the beginning without the written word! How much inspiration would have been lost to the world!

It seems certain, then, that all ideas and thought systems are the products of the last 8000 or 10,000 years. Men who were capable of inventing writing were certainly capable of many other ideas, and every material invention began as, or was associated with, an idea. I am not here concerned with pure thought as such, or ideas as such, but only with those ideas which could be translated into material objects, or instruments of culture.

It must not be overlooked that many tribes and races who have no written language of their own are within quite recent years sprung from peoples who did possess a written language. Isolated, developing apart, they have lost the art of writing; their spoken language has become first a dialect, then a distinct tongue. All the races and sub-races of central Asia have thrown off satellite tribes in this way.

The proud position Great Britain holds in the world today as a manufacturing country, no less than as a liberal-minded one, is in no small measure due to the firmness with which men in the West took each forward step, and to the improvements made in the application of each invention, notably writing. Without writing, nothing approaching our present command over nature, brought about by the high-powered machine, could have been built up. Nor without the invention of a comparatively simple and flexible script, combined with the rigid symbolical script of mathematics, could any further scientific advance have been made.

So much for technical achievement and material progress, which moved forward rapidly as more and more raw materials were brought into use. Is it not, then, dismal to reflect that the art of writing, invented more than 6000 years ago, and needing but the simplest tools, should today be practised by so few! In spite of the number of scripts in the modern world, their mal-distribution, and the small proportion of the total world population who can read and write *any* script, are things to ponder over. For at first sight it seems that a fundamental invention, essential to the progress and well-being of mankind, has spread over no more than a fraction of the habitable globe in 6000 years, since there are hundreds of millions of people who cannot even sign their own names. Surely, for them, writing might never have been invented?

Not so. Almost everybody in the world, whether he can sign his name or not, profits from the fact that writing was invented, and partakes in some degree of the benefits derived therefrom. It would be as reasonable to suppose that only those who themselves keep domestic animals, or grow crops, profit by domestication. That, indeed, is the test of a real forward step: though few practise it, the world in general benefits from it.

CHAPTER XIV

THE DISCOVERY OF TIME – I

NOWADAYS we live with one eye on the clock. Even those of us whose work is for the most part independent of office hours, railway time tables, the openings and closings of shops, banks, and all the other routine sequences of industrialized society, cannot altogether get away from time and its implications: 'It's time we did – something!' That immortal vagabond Huck Finn, who was adopted by the Widow, found the luxury life, punctuated by a bell at whose tinkle he had to eat when he wasn't hungry, go to bed when he wasn't tired, and get up when he was, too irksome to be borne. *He* lit out for freedom. But few of us are able to 'get away from it all'. We may struggle feebly against the tyranny of time, but we have worn our chains too long now to be altogether happy were they knocked off us. Set free in a time-conscious age, we might be at some loss to find ourselves wandering in so alien a world; yet even now, once clear of the city's iron grip, it is possible to get a glimpse of the happy, but now impracticable, long-ago before Man discovered time; at least, if we are content to lose ourselves amongst the vast majority of mankind – the peasants of the world – who still live by the faint illumination of primitive time.

From the day we are born townsmen at least inevitably become slaves to time, if only because it is the price of livelihood. Not even the rich can contract out of the time machine; on the contrary, the greater our possessions the heavier the yoke. Limited escape from the ruthless propaganda is possible only if we consent to exchange many of the harmless pleasures of life in return for limited freedom. How much time-propaganda we absorb today a little thought will show; for in this age of split-second precision, neither the philosopher nor the moron, neither the honest worker nor the sluggard, can escape from the strangling tentacles of time in the city; it stares him remorselessly in the face at every street corner. Whenever he looks up at a public building – certainly at any building connected with transport, such as a railway station, or with Big Business – he finds himself face to face with a clock, which reminds him of what he has to do next. Every hour – far oftener in our seats of learning – the noise of time smites him on the ear like the knell of parting day. Our language is full of proverbs, aphorisms, clichés, about time, which trip lightly to the tongue of the unimaginative: 'A stitch in time saves nine'; 'time and tide wait for no man'; 'no time like the present'. We kill time, race against time, and perform many other wanton acts of bravado. Sometimes it seems so plentiful that we even waste time.

Nor is this all. Sports editors fill a page of our newspapers daily, and it is seldom they cannot, by hook or by crook (generally the latter) enliven us with a record in some form or other; and a record, in their sense, almost invariably includes an element of time. Sports writers (and meteorologists) are tireless in ferreting out these barren facts; few are proof against damming the flow of their prose with such monumental dolmens – a reference to some obscure and unworthy record which has no bearing whatever on the current game. Of course, it is athletics in the old Greek sense which furnish the bulk of these discursions; flat races stand or fall by time records. Not content with a single clear-cut record, newspapers divide and sub-divide them, so that you get more for your money and can take your choice.

Thus a world record can be made to include a European, an Empire and a British record – each with frills. *Parvum in multo.* As for games and contests generally, he is a poor ornament of the sporting press who cannot intrude a record into the account of a football match, even if it is only a record 'gate'; while the cricket reports glitter with them. Thus: 'Baraclough had knocked up a century in fifty-five minutes – a record for the ground.' 'The partnership had yielded 200 runs – a record fourth-wicket stand.' 'Chalkshire were all trundled out by Pease and Beans in sixty-five minutes, the fast bowlers thus eclipsing their record against Mudshire, who had lasted just twenty minutes longer.' And so on; the record's the thing.

Further, the incalculable importance of time is shown by the setting aside of taboos where it is concerned. In England, at any rate, it is taboo to address a stranger – unless, of course, you yourself are a stranger in the district, when it is permissible to ask the way; even then it is better to ask a policeman. But there are just two questions you may ask, and which, in fact, are constantly being asked. The first is: 'Have you a match, please?' (Not so common today, perhaps.) And the second: 'Can you tell me the time, please?'

I emphasize these points, and particularly the propaganda of the time theme, to indicate how extraordinarily difficult, if not impossible, it is for us to visualize the conditions under which early Man lived before time first dawned on his consciousness.

In this age it is difficult enough to understand the peasant mentality of the great cultivating class, especially the peoples of Asia and Africa, who live by the changes of the moon, in months and seasons; how, then, can we hope to read the mind of Stone Age Man, wandering across the vast spaces of the world! All these people are far less engrossed with time than are we of the industrial West. I have hinted that, in the face of this perpetual barrage, even the few who are bored by the sporting press, who hate town life, and who are prepared to arrange their own lives in return for a trifle of freedom, cannot get entirely out of range. Time is implicit in the very air we breathe, the books we read, as well as in the work we do. How, then, it may be asked, can it be said that Man *discovered* time? Surely time has always existed; is it not, as we say, part of the order of nature? I think we shall find that, quite apart from the invention of instruments to *measure* time, and of observations to find something we *can* measure, time itself had first to be discovered. It required prolonged observation and deep thought, not instruments.

Let us therefore start at the beginning and try to see the world as it was before Man vexed himself with ideas about time. For Man, in the beginning, was no more conscious of time than any other animal is conscious of it. He had to become very intelligent indeed before he could discover time; we may be sure that it is a comparatively recent discovery, made, say, well within the last 10,000 years. We see the peasants of Asia, poorer but more carefree than ourselves, because they are not concerned with hours, or even with days, but with seasons and the moons which mark their progress – which is true of life on the land the world over.

If, therefore, we wish to stand outside our prison and look at time as it were from a little distance, so as to put it in the correct perspective, the first thing we must do is to get away from the city with its shrill emphasis on time, and try to forget 'the sly, slow hours'. The men who wrote that 'the evening and the morning were the first day' used the only unit of time they knew. Those words were written perhaps 6000 years ago, before the full discovery of time.

Animals have no knowledge of time. They recognize day and night, hot weather and cold, perhaps wet season and dry, but no more. We all know that those animals, and especially birds, which are abroad by day retire at sunset, and sleep or roost during the night. They react to darkness and light. At dusk their place is taken by quite other creatures – the crepuscular world of bats and owls, shrews, nightjars, hawk-moths, glow-worms and many others. By the time night sets in an utterly different fauna from that of the day is in motion – but, in our temperate latitudes, night life is confined to the summer months; hardly anything but the fox is abroad on a winter's night.

Even vegetation is sensitive to the onset of darkness, a reaction which is most conspicuous in the warmer parts of the earth, where in the evening many trees droop and fold up their leaves as though they too would sleep. Many flowers also open only at dusk, to die at sunrise. A careful survey of any area, especially in regions prolific with life, such as the foothills of the eastern Himalayas, or the Malayan jungle, would reveal wide divergence between the day and night animal populations, including, of course, insects; as well as considerable movements in the vegetation. The difference between day and night is certainly appreciated throughout the world of life, right down to the simplest unicellular creatures, many of which possess a highly sensitive eye-spot; this reacts immediately to light.

Again, both animals and plants recognize the onset of winter, reacting in a hundred different ways to the change of season, whether it be a change from hot to cold, or from wet to dry. Bird migration, hibernation, the shedding of leaves and formation of winter buds, colour changes of plumage and of fur no less than of leaves, even the times of flowering and of ripening of fruit, are seasonal. All these familiar events, and many less familiar, are slow responses to the rhythm of seasonal change.

Man is no less sensitive to the alternation of day and night, of winter and summer, than other forms of life, and has been acutely aware of seasonal change from the beginning. But he had to become conscious of rhythm – not merely react automatically to light and heat like a vegetable.

Time has no real existence, certainly no meaning for us, until we recognize and *remember* a constantly recurring period which we can subdivide; and to primitive Man the knowledge of such a period would not come easily. The most easily recognizable rhythm is the alternation of day and night; but from the time point of view day and night are almost useless. To begin with, they are too small a unit, and soon involve one in large numbers – the last thing that a creature who could not write, and who probably could not count, would be able to cope with. To the simple peasant, even years mean little. The passage of time is as vague and blurred in his mind as the distance between two villages some miles apart. The hillman in Asia does not know his own age to within several years, nor does this trouble him at all.

A more formidable obstacle is, of course, that no two consecutive days are ever quite the same length, and that the difference is ever increasing or decreasing. Even in comparatively low latitudes, such as 30° on either side of the equator, the difference between the longest and shortest days is about three hours. Finally, if further argument is needed, who could decide when a day began and when it ended?

Thus the inescapable fact of alternating day and night was of very little help in the discovery of time; still less helpful was the faint change of season in the dry sub-tropical or warm temperate belts inhabited by early Palaeolithic Man.

There remain the heavenly bodies: sun, moon and stars.

If we are clear in our own minds as to what is required before we can become conscious of time, we may find it easier to understand how Man came at last to discover it. For us, time passes slowly or quickly according to the interest to ourselves of what we are doing. A week in prison may drag like a year; a week's holiday may be just a week; and a week immersed in an exciting piece of research may vanish like a day. Experience furnishes us with the idea of time, memory reinforces it.

What is needed to give us even that distorted sense of time is the periodic recurrence of an event outside ourselves, the number of days or nights between the recurrences being always the same; that is to say, the constant periodic recurrence of some familiar event. That gives us a unit which can be subdivided into smaller units such as days and nights – units which, so far as early Man knew, would be comparable wherever he might be. To be of any practical use to him, the unit chosen must be neither too short nor too long; it must, in fact, bear some relation to the human life span. Assuming that the expectation of life of primitive Man was about thirty-five years – and it could hardly have been much more – he had to find a comparable unit before he could hope to grasp the idea of time. Whether the average life span is twenty-five years or a hundred, a year is a useful unit; it certainly bears a reasonable relationship to any known human life span, whereas a day, or even a month, does not.

But it took Man many centuries to recognize the year. As we have just written, the essence of the discovery of time is the recognition of some natural rhythm outside oneself, resulting in the constant recurrence at not too infrequent intervals of a certain event. The only periodic events which nomadic Man would be likely to recognize as such would be new moon and full moon; or at any rate the waxing and waning of the moon. Remember, he had no means of recording events, present or past, except by such crude means as cutting notches on a stick.

The moon, however, is nearly always visible in a clear sky at some time of the night, and every twenty-eighth day it is at the full. A full moon is easily remembered – once Man has memory. It recurs with such frequency that primitive nomadic Man probably recognized and remembered its habitual appearance – that is, assuming he lived in a dry region where the night sky is usually visible.

It would be possible, though difficult, for primitive Man to keep a tally of twenty-eight days – though how many of us who do not keep a written record recollect the last full moon, or know the age of the moon on a given date! Even if we write a daily diary, such things are apt to be taken for granted as part of the unchanging order of nature, and hence not worth recording.

But that jibe is not quite fair. There is another much more potent factor than laziness which militates against *our* knowing how old the moon is – the English weather. The chances of our seeing two, let alone three or four consecutive full moons are considerable; and until he had watched the moon night after night for years, primitive Man would have little cause to note any periodicity in its behaviour. Its steady waxing and waning over a short period would only dawn on him gradually, and not by any means on every man.

Which of us in our youth have, by our own untutored observation, noted that an easily recognized constellation such as Orion, or a brilliant star like Vega, is rising in the east at one season of the year, just as darkness falls, and setting in the west at dusk six months later? Of course, we in England can provide a number of reasonable excuses why, in fact, we would be very unlikely to notice anything of the sort – our dim skies, our city streets like slit trenches, and so forth. But even if we lived in the great open spaces, other factors – our many interests, our concern with more 'practical' things, the fact that we take time, the calendar 'and all that sort of thing' for granted – would prevent all but a very few from remarking anything peculiar about the stars, though we might start asking questions about the moon. Nevertheless, a few exceptional children would notice the lagging stars.

Thus we can easily perceive how difficult any large generalization would be for nomadic Man, with nobody to answer his questions. It would take a long time for him to realize that the number of days between one full moon and the next was *always* the same; to a nomad this was not obvious. Still, eventually he got that far.

We have discussed how, long before he became Man, ape-man (conscious of cold and warmth, unable to migrate southwards like the birds) learnt to make fire, which gave him warmth and also light at night. To early Man, then, there was day and night, and there were seasons which followed one another and repeated the sequence. Man anywhere outside the tropics, certainly in North Africa, the Middle East generally, and in northern India and China, would soon become conscious of the winter and summer sequence. He would notice, too – though no doubt much later – the waxing and waning of the moon. With all this, he had at least (though he may not have realized it) the elements of time; the germ of the time idea was within him. Just as there are children well above the average in intelligence today, so we must suppose there were exceptional men 10,000 or 100,000 years ago who might begin to put two and three together.

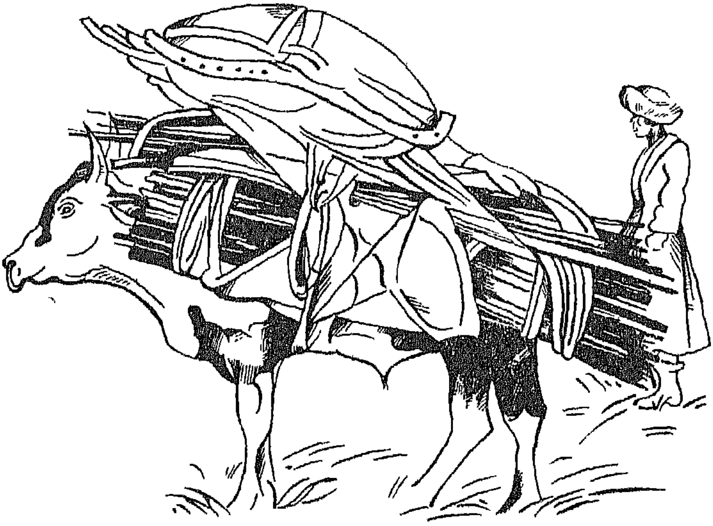
In suggesting that time was discovered well within the last

10,000 years, it must be clearly understood that this discovery of time has nothing whatever to do with causes, or with the means for accurately measuring time; still less is it concerned with philosophical or metaphysical ideas to the meaning – or existence – of time, or its relationship with space. To the present writer, time means exactly what it probably means to the reader: not a subjective phenomenon, not a part of the natural order, but just something you read off the clock or the calendar. Speculation about the shape of the earth and the movements of the heavenly bodies are much more recent than the discovery of time, and are concerned with the why and the how; but they are not themselves time, nor are they necessary for time-consciousness.

What was it that finally forced Man to discover time, that held him back so long as it eluded him, and sent him bounding forward as soon as he had a glimmering of what was time? When Man ceased to be nomadic and settled down to gardening and agriculture, the necessity for a measure of time, for the recognition of seasonal repetition, arose. For centuries he had known the seasons come and go – hot and cold, wet and dry. But seasons steal on one almost unawares, especially in the middle latitudes where civilization had its earliest roots. Man required an exact date for preparing the soil and sowing the seed; no longer could he be entirely indifferent to time.

One must suppose that cultivation began with people camping where the desired plant grew, encouraging its success by weeding out competitors, exactly as is done in some parts of the world today, rather than by collecting seeds and sowing them near the camp. So long as Man went to the plant, he was not concerned with a time for sowing. That came later.

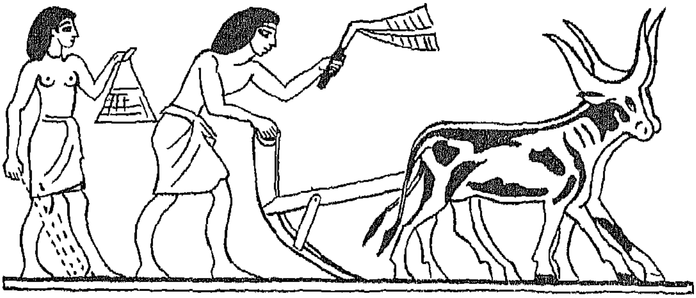
But as soon as he began to collect seeds and to sow them in prepared ground at some little distance from their original home, the problem would arise – when was the best time to sow? His only method of discovering this would be trial and error, although he would doubtless have a vague idea of when the growing season began. We are not here concerned with the vagaries of seeds and their proper treatment, although it is pertinent to remark that the problem is not a simple one. What we are concerned with is how, having sown the seeds at various times and got the best result – *how* was he to know at what interval to repeat the process? In other words, when agricultural Man had, by trial and error, found the best season to sow his seeds, how was he, without knowledge of a time-cycle, to recognize the same season (to within a few days, perhaps) when it returned? Or was that



Kirghiz of Soviet Asia move to new feeding grounds when the old ones are exhausted.

a matter of no importance, so long as the weather was suitable?

In Britain, at any rate, almost any weather may come at almost any season, and though there is probably less scope for error on the fringes of the desert, the danger exists, and it seems unlikely that reliance on the weather would prove a satisfactory guide to the correct planting season.



Egyptian tomb drawing showing sowing and ploughing about 6000 years ago.

We may then feel confident that it was agricultural Man who first needed to recognize the onset of the seasons with more precision than even the closest observation of animals and plants, or his own sensations, had hitherto enabled him to do. If he could see the moon four nights out of five, and not only the moon, but a good slice of the sky too, undimmed by cloud, surely he could keep a tally of the full moons, sowing his crops, say, at the season of the second full moon. But – second full moon from what?

CHAPTER XV

THE DISCOVERY OF TIME – II

THERE lies the snag. Can you, in an infinite series of full moons, choose some arbitrary starting point (call that the first moon), then, keeping a tally of full moons, return to your starting point and begin the count over again? You can – if you know how many to count! But *how many* moons must you count? *We* know, because we have often been told, that there are thirteen moons (and a bit over) in a full year; but Man had first to discover that. It would be difficult enough to keep the tally correctly; more difficult to know how many moons to count before starting over again. Besides, *why* start again? One moon is just like another. Even if Man did observe that there was a seasonal repetition after so many moons, the irregularities in the weather are so great that he would never know where he was; the rhythm of the moon corresponds with no rhythm of the weather.

But suppose that by chance or by prolonged trial and error Man did happen to hit on thirteen moons between one planting season and the next, or between one rise of the Nile, Indus, Euphrates or other river, and the next – what then? At the end of a century, with no written records and no tradition established, he would be nearly a month out of his reckoning – that is, if his tally was correct. This error would continue to accumulate until his planting season, originally fixed for March, let us say, had been advanced to May or June. Imagine the chaos and uncertainty! Agricultural Man, being an intelligent creature, would realize in a century or two that as a time keeper the moon would not do. One moon was too much like another. After centuries of effort, groping in the dark, watching the night sky and the triumphal march of the stars behind the sun, Man was not yet time-conscious. He still needed a cycle of events, more accurate than the waxing and waning of the moon, and longer too, before he could acquire a sense of time. Above all he needed *memory* – probably one of the latest improvements in his makeup.

True, the peasant world of today, which includes the vast majority of mankind, still reckons time by moons, thinks in terms of moons and seasons. But the moons have long since been tamed and pressed into a rigid framework. No longer can they misbehave; they occupy a subordinate position. We have seen what a web of difficulty Man span for himself when he cried to the moon to teach him the secret of time. It wasn't there. The moon was a clue, but not a solution.

However, once Man had begun to speculate about the moon, it seems natural to suppose that he would also speculate about the sun, that life-giving orb, warm and comforting, which rose and sank, and crossed the sky each day; and at whose going down night fell and the moon and stars came out.

Would early Man have noticed that in summer the days are longer, and that in the cold weather the nights are longer? He could hardly fail to do so in Britain at least!

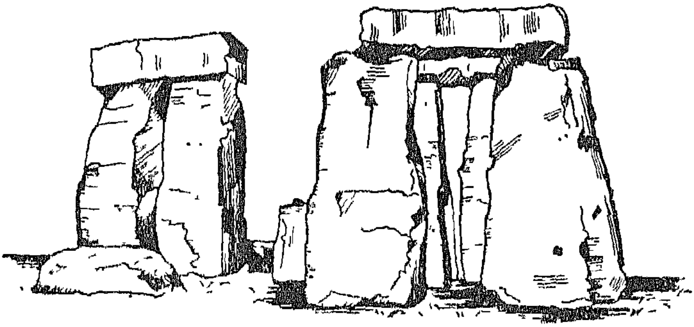
But if Man inhabited bleakest Europe at all during the period which we are discussing, he was certainly savage Man. Intelligence was dawning amongst the nomads who lived in those dry lands where the earliest civilizations were about to arise; but scarcely amongst the scattered dwellers in the cold forests of northern Eurasia.

However, even in mid-latitudes around 30° there is enough contrast between summer's heat and winter's cold to be noticeable; while the difference between the midday height of the *sun* in June and December in a region where it is rarely obscured by cloud, namely 47° (i.e. 7° from the zenith in June, 54° from the zenith in December), is sufficiently obvious. Surely it would have occurred to the brightest people sooner or later that there was some connection between the long, hot days of summer with the sun overhead, and the short, cold days of winter with the sun low in the sky. He would see sunrise and sunset too, day after day, year after year, though he may have watched it thousands of times before he became time-conscious. Inevitably, however, a season would come when he *must* notice that the sun rises – and sets – in a different direction, winter and summer, as well as being higher and lower in the sky during the middle of the day. He could make nothing of it, of course. He lived on a flat earth. (It is not necessary to go back to primitive Man for that belief; did not Kipling write of an English village which in this twentieth century voted the earth was flat?) The sun rose and climbed the sky, dropped away and set over the rim. But at least it happened with great regularity, and the same with the moon. He might not ponder too deeply on such everyday occurrences; he was fully occupied with his daily search for food, ever on the alert for enemies. But at least he observed them – causes were hardly in his line.

We may, however, be quite certain that only in regions where the sun can be seen regularly by day, and the moon by night, could Man draw any conclusions which added together would build up into a generalization – and the discovery of time. Not in the cold, misty northern lands, nor in the hot, steaming tropics could Man possibly have become time-conscious. It was the dry climate of the middle zone on the fringes of the desert that enabled him to make the momentous discovery of time, whether it was in Africa or Asia.

What seems certain is that at some time, not so very remote, Man did begin to take more than a fanciful interest in the sun. Indeed, he received such favours from the sun that it is likely he worshipped it from the beginning. He did begin to notice that it rose in a different part of the sky as the days grew longer, and it did move further overhead about the middle of the day. He did not, we may suppose, trouble himself with reasons. Why should he? He was concerned with facts. He had already observed the rhythmic movements of the moon. Now he observed that the sun also performed a rhythmic motion more complicated than that of the moon. That the earth on which he stood moved with a certain rhythm was still far beyond his comprehension – it was not a thing which he could observe directly for himself. Nevertheless, the rhythm of day and night and of the seasons was beginning to have some meaning for him – he was learning to acquire a sense of time. Might not the fact that people – his own people – died, and were born, also suggest a rhythm? No time-consciousness seems possible without a sense of rhythm, a knowledge of nature. Man discovered time by means of comparison – for time *is* comparative. There is no time except by comparing one event with another. (This in no philosophical or metaphysical sense, but in common sense.) The difficulty for early Man was, of course, the lack of knowledge and experience of the individual man. He had no stock of recorded knowledge on which to draw, no written records. Each man had to depend on his own small experience. Until he ceased to be purely nomadic, until he began to settle down in cities, it was impossible for Man to acquire the time sense.

And then came stone circles, arranged, it would seem, with the object of discovering the equinox; for if the long day and short day seasons alternated, the length of the day increasing gradually to a maximum, then decreasing again, as gradually, to a minimum, there should be some neutral point when day and night were equal. And so it turned out; only the stone circles were aligned on midsummer day rather than on the Spring equinox. Man could not follow the moon; its speed was too great. But the sun moved with a slow majestic grandeur, not across the sky in a day, but down the sky in a season; and Man (whose wits were yet slow) could keep up with that.



Stonehenge Some of the trilithons

In spite of all that has been written about it, the best authorities maintain that nobody knows the meaning of Stonehenge, our own most famous stone circle. Nevertheless, we know on the authority of Graham Clarke and others that 'both Stonehenge and Woodhenge are oriented in such a way that the axis of each points to the midsummer sunrise'. Stonehenge in its earliest form is reckoned to be of late Palaeolithic age, the 'late' referring to this culture as developed in Britain. But the stone circle was not invented in Britain, and may have taken several centuries to reach Britain. Assuming Stonehenge to be perhaps 4000 years old, dating from before the Beaker invasions, the first stone circles ever built might easily be another thousand years older. We can be pretty certain that 8000 years ago men were beginning to grasp the idea of time, and that by the beginning of the Neolithic Age they were more or less time-conscious.

Suppose the long diameter of a stone circle to be aligned on the summer solstice, it would be quite possible to keep a tally of the days, or at least of the moons, before the sun again rose at the same point, thus giving the priests — for these early buildings were no doubt also connected with religion — the idea of a year. It would be politic for priests to have knowledge above the ordinary, and hence be able to direct the peasants in such things as the proper time for sowing. It is even conceivable that they were able to mark the furthest point south reached by the sun. It is rather remarkable that no effort appears to have been made to mark the highest and lowest points where the sun crossed the meridian until much later; perhaps not until after the discovery of the lode-stone. But it is comparatively easy to observe the point on the horizon where the sun rises or sets; it is less easy to say when it is on the meridian, especially if it is close to the zenith.

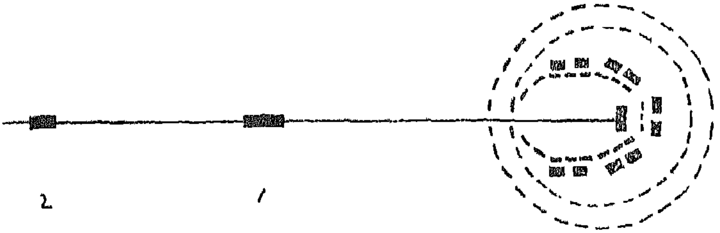


Diagram of Stonehenge stone circle. On the morning of the summer solstice the sun rising behind the Slaughter Stone (1) was aligned by the Heel Stone (2) to a point within the sanctuary. It was the signal for the priests that the New Year had begun.

With the discovery of the year, however crude the approximation, and its seasonal divisions (though these latter may not have been very sharply marked off from one another), Man may be said to have discovered time, to have become time-conscious. It probably took centuries to complete the discovery, which began with Palaeolithic Man watching the moon, wondering vaguely . . . counting full moons . . . and ended with the realization that the sun also moved otherwise than straight across the sky. Probably the stars did not come into the matter till much later, when a higher degree of precision was called for.

Agricultural Man, even more than nomadic Man, needed to be time-conscious; and having now fixed a time for sowing and a time for reaping, he was well on the way to becoming one of us harassed humans, pursued by the unforgiving minute.

Nowadays the time idea has become so mixed up with geography that it is difficult to disentangle the two. But time-consciousness must have preceded any conception of geography by centuries. The first step in geography was, surely, recognition of the fact that the Earth is round; a discovery (as mentioned in Chapter II) usually attributed to Eratosthanes, although we may be sure that several philosophers had a hand in it. Without the fact of the Earth's roundness, it is impossible to conceive of any basis for geographical study.

Further than that, there is a metaphysical explanation of time, inconclusive to the layman who has to catch a train to the office every day, and who looks forward to next Saturday's football match. Even the metaphysician likes his breakfast at eight o'clock. We are not, therefore, going to concern ourselves with those people who tell us that there is no such thing as time.

The part played by time-consciousness in the life of social Man is so vital that it is hardly too much to say that no society which was ignorant of it could hold together for a day. Indeed, it is impossible to imagine a society existing without it. Only a dumb herd could do so. And if the same might be said of those conceptions inherent in the human spirit, I reply 'Yes' – but Man could not discover these concepts outside himself, as he could discover – and *had* to discover – time outside himself.

I have put the discovery of time last, because it is not something you can touch and see, but rather an experience. Nevertheless, like the machine, Man had to discover it for himself. How long ago he did this we do not know; but it must have been one of his earliest discoveries.

CHAPTER XVI

WHERE THE RAINBOW ENDS

WE have now discussed the several steps which set Man firmly on the ladder that reaches to the rainbow. All of them sprang from the human brain during the last 8000 or 10,000 years; those steps which afford him work and happiness, a sense of striving not for himself only but for the common weal. What of the next step?

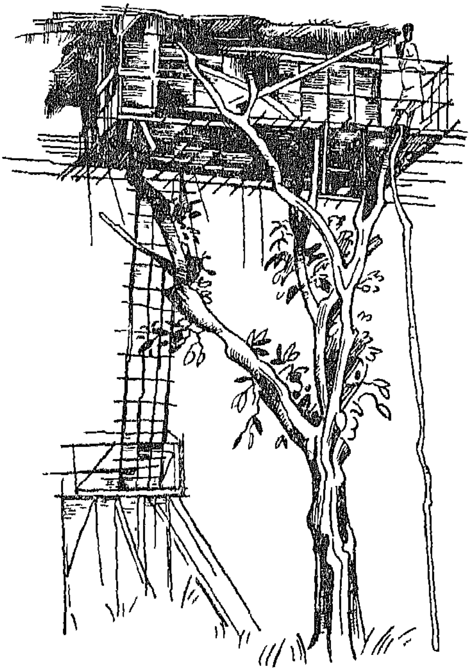
For Man is not always and everywhere happy – far from it; naturally one asks: why not? We all know from experience the deadly drag of frustration in the world, the feeling that one *could* do something useful, that all one wants is to be let alone to get on with it, but that one is somehow prevented by a thousand small hindrances and irrelevancies, resulting from the friction of one man's mind on another's. Everywhere the world's work is being slowed up or jarred by frustration. I cannot diagnose the present sickness of mankind, nor is this the place to attempt to do so. Personally I doubt if it is a new sickness. More likely it is as old as society itself, and before long society will recover, relatively, as it has ever done in the past. It is not mortally sick. Meanwhile Man goes forward, preparing for the next step.

Agriculture, by concentrating food, made it possible to concentrate men. The domestication of animals still further concentrated food, besides giving Man rest from his labours. The machine further lightened his burden, while the power machine gave rest to his animals also, while making possible work which neither men nor animals alone could ever do. Then the invention of writing, which recorded Man's observations and fleeting thoughts, in any part of the world at any time, built up a body of experience and tradition which enabled new ideas to be conveyed to whole peoples, far away in time and place; while the discovery of time put rhythm and order into life. Meanwhile thousands of raw materials existing on this earth long before Man appeared – some in the rocky crust, some in the air, some in the sea – were finding their way into daily use, helping to broaden men's minds, increase the range of ideas, and add to the general comfort and welfare. Each of these key discoveries spread gradually over the whole world, was adopted everywhere, and in the course of time bestowed great benefits on the human race.

Yet it would be idle to pretend that Man has had no setbacks. We see him advancing from strength to strength, but we ignore the lapses. Though tide creeps on, each wave recedes. It is not that Man has taken a wrong turning or lost the way, but that he has too often halted, even turned back. It is the ill-use of great discoveries which leads to frustration and disaster – not the discoveries themselves.

It is obvious, too, that the spread of ideas has not kept pace with the rate of increase of population; thus more and more people get left behind. The importance to civilization of the fundamental steps took centuries to reach the ends of the earth – some of the later ones have hardly done so yet. All men know the secret of fire, without which there could have been no civilization at all; but fire was invented before Man was Man. All men today possess at least one domesticated animal – the dog – although it provides neither labour nor food directly, but no doubt fulfils its earliest role of watch-dog and hunter. Further, there are probably no people in the world who remain ignorant of, or uninfluenced by, the simple machine and its implications. But the power machine has not yet travelled far from the main industrial centres, and even its products are spread thinly, barely reaching the heart of the continents.

We know what the machine has done for the West. But compare a small farmhouse in Britain with a tribal hut in the jungle-clad hills of Assam, where also the people live on the land. The latter may boast a frame bed with a string base, and dry bracken for mattress, a number of metal and earthenware pots, a fishing net weighted with lead, and a variety of implements and receptacles made of wood, cane, or bamboo.



A borang or tree-house in which people of the Garo tribe live in the cultivating season so as to be near their crops.

The hut itself will be made of split bamboo – possibly covered with mud – thatched with palm leaf or grass. There will be ropes made of liana, some hand-woven cotton cloth, probably dyed, and together with a few animal skins used both as wearing apparel and bed-clothes; perhaps also a stone or wooden quern for husking grain. The discerning will note that there are very few objects which are not made from local raw materials, and made by hand. More materials enter into the construction of an English farmhouse – let alone its contents – than the Assam tribesman has ever known.

Other inventions, too, have lagged behind. Writing, for example – though as noted in Chapter XIII the whole world has been influenced by writing. Improvements and mechanization, printing and the typewriter, have followed, but none of these have added anything fundamental to civilization, though they enabled more people to benefit from the invention of writing, spread ideas more quickly, and increased their range. They make the hard road smoother, but they do not inspire us to turn off along a new road. Printing was one of the earliest examples of mass production.

All this is not a matter for surprise, still less for despair. The firmest steps have hitherto been separated by centuries, while each was being assimilated.

What effect have these unfaltering steps had on Man himself? Do our heroes of today differ in spirit from the Greek heroes of the nursery tales? Assuredly not. Again, our sages utter much the same advice as those old Chinese philosophers whom we admire. We try, not too successfully, to live by those rules of conduct laid down by eastern men 4000 years ago, and recorded in the Old Testament. In fact, for all the immense changes in his outward circumstances, Man has not changed in his general outlook within historic times, and for several thousand years before that perhaps.

But we have only to go back far enough to find change and decay in all around, including Man. No one would be so naive as to suppose that Neolithic Man, for example, thought and acted like modern Man. Compared with the rest of creation, he was no doubt *sapiens*; but he would surely have been hard put to it to get by in 'well informed circles' today. He was, we may suppose, an unregenerate individualist with a myopic outlook. As for Palaeolithic Man, even the brutal looking Neanderthalian (who was certainly Man, not ape) left much to be desired as a companion; while his contemporary Peking Man was, it seems, a cannibal.

We know, however, that between the age of apes in the far distant Miocene period, and the coming of Neolithic Man, several other species of Man have walked this earth, possibly at one and the same time. Yet only one of them – modern Man – has survived into the twentieth century. He must, therefore, have been the fittest to survive. Indeed, so successful has he been during the last few thousand years, that there can be no serious threat of his extinction while the world lasts. Even the enormous change in the conditions under which he lives have had little effect – and this in spite of the fact that he himself has brought about much of the change. Hence we believe there is no reason why he should cease to invent machines, to change the face of the earth, and to dream dreams, which he will presently set in motion. And since 'unchanging' Man has, during a span of 8000 years more or less, taken those forward steps which are the theme of this book, there is no reason why he should not take another, be it in fifty or a hundred or five hundred years' time. In fact, it is certain that he will.

I have not, I hope, written as though the story of Man was factual and fully documented. History, and still more prehistory, is largely a matter of personal opinion coloured by prejudice; but this does not alter the fact that the expert is better equipped to form an opinion than the non-expert, and owing to his wider experience, able to form more mature judgments. The facts, where they exist, are not in dispute; it is their interpretation which is elastic. But facts are not history; history is made by their interpretation. Hence there is no warrant for the saying of a peculiarly distinguished American that 'history is bunk'. It depends on who writes it.

The fact remains, I have been unable to find even two authorities who are agreed as to the age of Man, or of the Neolithic invasion of Europe, or even of the age of *Homo sapiens*. Nor, at this stage of the investigation, should I expect to do so. There is no science in which such far-reaching deductions are made from such slender clues as in archaeology and prehistory.

If I have given the impression that the history of Man has been a mere game of consequences – Neanderthal Man met *Homo sapiens* at Stonehenge; he said: 'Hullo stranger! What brings you here?' and she said 'Forty years on' – I must not be taken too literally. There are authorities, such as William Howells in the U.S.A. and Dr. L. S. B. Leaky (who is responsible for a vital clue from East Africa) in Britain, who believe that *Homo sapiens* himself is not the social upstart most people believed, that in fact he may have existed in Middle Pleistocene times or earlier, which, to come down to dates, means 50,000 or 100,000 years ago.

If *Homo sapiens* did indeed exist unhonoured and unsung in the Middle Pleistocene – a phrase which might cover several hundred thousand years – then, no doubt, the successor of modern Man is already in our midst, working out improvements for our future, helping us prepare the next step. And which of us has not, once or twice in a lifetime, for a fleeting moment felt the influence of such a power, perhaps in the presence of a complete stranger with whom one has suddenly felt immeasurably at ease?

I have intimated that since the invention of the power machine no irrevocable step in civilization has been taken – and *that*, indeed, is the test of our footsteps: they *are* irrevocable – in spite of a vast amount of preparatory work. But is that quite true? More than one distinguished man of science has given out that the release of atomic energy is the greatest discovery made since ape-man discovered fire!

If that is so, it seems improbable that we would recognize the fact so quickly. The researches which led, directly and indirectly, to the release of atomic energy are less than fifty years old. Nobody has yet benefited from it; and in spite of optimistic reports – already less optimistic than they were – it will certainly be a century before anybody does. If and when power is on tap from atomic energy, it will have at least this much likeness to the invention of writing, or of the power machine, and other footsteps: the vast majority of mankind will have to do without it, and will continue to do things in the good old way, even to wearing out their bodies with hard labour.

Thus I fail to see any resemblance between the discovery of atomic energy and the discovery of fire. The importance and permanence of a discovery can only be judged by its effect on mankind, not by its complexity. The frivolous may say that the effect of the atomic bomb on the world was considerable; but that is not quite the point. The real point is: *who benefits?*

What, then, in a word, is this civilization of which we are in search? Clearly, it is not mechanization. Looking down the long vista of the years, we may be sure that the future of civilization does not lie in the machine. Neither did it lie in the invention of writing, or in the domestication of animals. These discoveries put us, kept us, on the right road; but we have still far to go – civilization is always where the rainbow ends. Yet there is no reason why we should not some day reach our goal. We may be on the right road, and it leads on and beyond the last of our footsteps – the power machine. If we are not on the right road, we shall presently discover our mistake and turn aside.

Some two centuries have passed since the invention of the power machine, and today it can be made to do almost anything that Man can do, besides much that, unaided, he cannot do. Almost, but not quite. It will build a battleship, or cut and polish a gem till it shines like a star, or play the piano. But as pointed out in Chapter x it cannot compose a symphony or write a poem, or tell a story. It is not *human*, and therefore it is but a tool to do Man's will. It is a tool which everybody uses, and which the world will always want, but still no more than a tool.

If we despair because we fear that the next step is too long a-coming, what of the previous step? Two centuries is nothing. But between the invention of writing and the next great step, which was the invention of the power machine, 6000 years rolled by. Nor was Man idle during all that time.

It would seem, therefore, that for all the intelligence and faith of Man, world-moving discoveries are not very common. We may still have to wait a century or two before we see another beacon. But of this we may be certain: it is already on the drawing board. Meanwhile time has us by the throat. If we lose our nerve now, we may recede for a thousand years. We must, then, at all costs hold on.

To return to our question – what is this civilization we are in search of? Since it is not any one of the steps (least of all mechanization), nor all of the steps together (which are but means to an end), what *is* the end? Amidst the clang of machinery, we in the West have become somewhat bewildered and confused; we tend to lose sight of the fact that the mere enlargement of industry and increase of speed do not in themselves mean a higher civilization; they mean a higher standard of living – more houses and suites of furniture and fittings and ornaments and clothes; more comfort, heat, light and power; better cooking and better health for a greater number; more happiness, one hopes.

But a higher standard of living does not of itself bring about a new vision of life, like the footsteps we have chosen as beacons on the road to our goal. Many luxuries are merely nuisances. There is no limit to luxury, but there is a definite limit to comfort. Without attempting to spin a philosophic web, I would maintain that civilization is a sense of responsibility; responsibility towards oneself, towards mankind, and towards God.

What else could it be?

EPILOGUE

TWENTIETH CENTURY

AT this point I was minded to stop. It seemed to me that with the discovery of the power principle and the invention of the power machine to do his work for him, Man had again slowed to a halt, reached once more the parting of the ways; that the last material forward step had been made several centuries ago, and that meanwhile he was experimenting and improving on all his inventions and discoveries, no doubt preparing himself unconsciously for the next forward step; but that he was not yet aware of the next step, the how or the whither. Now I am not so sure. It may be that Man *has* taken another irreversible step, that he has made one more stride forward, or at least that he has chosen the path and is already in mid-stride. Atomic energy is born.

To the common man, atomic energy is inevitably symbolized by an extra big bang over Hiroshima. Inevitably he sees atomic energy as the atomic bomb, which is (in his view) just another bomb, larger and louder and much more destructive than any previous bomb, but still a bomb, producing an explosion; just as a bomb filled with T.N.T. is more destructive than one filled with gunpowder.

But *is* atomic energy just that? *Is* it no more revolutionary than, say, the change from external to internal combustion as a more efficient machine? Or is it a totally new departure, as fundamentally different from anything which has gone before as the invention of writing, or the recognition of natural power, and therefore liable to alter completely the pattern of world society? Is it, for better or worse, just a new source of energy, comparable with the substitution of steam for wind? Or is it something much more than that, a clean break with the past, pregnant with undreamed of possibilities?

Before we can reach a decision on this difficult question, and recognize atomic energy for what it is, we must first get away from thinking of it in terms of the atomic bomb, which is a caricature, and anyhow merely one of the innumerable possible uses to which this form of energy can be applied.

The question again arises: how are we to recognize those irreversible steps which we have claimed to be revolutionary, amidst the interminable shuffling and jiggling in which the greater part of mankind indulges – the to-and-fro movements round an endless maze of intersecting circles? Unless we can apply some test, it seems to me that the choice of permanent footsteps becomes almost arbitrary; and while few would dispute the discovery of fire, or even the invention of the machine, to be fundamental, more doubt exists with regard to the later steps claimed to be fundamental, and particularly to the discovery of atomic energy. And the best test we can apply is, I believe, that of irreversibility. When a better appliance is invented, the inferior one goes out of action, or becomes a curiosity. Thus electric power replaces steam, even on the railway. But fire and writing and power and agriculture are never replaced. They are universally used, and are permanent, irreversible.

I have written almost as though Man invented writing, or discovered the secret of power, in a year or a month, even in a day; almost as though yesterday there were no writing, and today all men could write. Yet we know quite well that writing did not come quickly or easily, nor the cultivation of plants, nor any other oblique leap forward. Each step took centuries to complete, and the further back in time we go, the longer we may be sure they took, not only to establish themselves in their place of origin, but to spread throughout the civilized world. (This spreading throughout the civilized world, this general acceptance by every race and every culture, is itself a criterion of advance in the sense in which it is used here.) On the other hand, the further back we go, the easier it is to pin-point the idea; to say, as it were, yesterday men were without domesticated animals, and on the morrow, lo and behold! they were conserving their strength, by reason of having domestic animals to drudge for them. A simple analogy will make this clear.

Suppose you stand at the top of a gentle rise looking all round you. The time is midnight. In one direction stretches a long, wide, empty street; and the street lamps are lit. To right and left, close to where you are standing, the nearest lamps, both in front and behind, throw a dazzling light, so that you cannot be sure whence the flood of illumination in which you stand is derived. Many objects can be half-seen in the pooled light, dimly or easily, amidst a confusion of shadow; they distract you somewhat from the lights themselves, but you are not always certain which are things and which are shadows – or even which are lights.

As you look down the long street, however, the lights on either side become more and more sharply defined, the distances between them disappear. It is the lights themselves now that are sharp, not the things. All else is in deep shadow. Each light becomes a point, everything else has vanished, even the distances between points – until you start to walk down the road.

Similarly, looking down the long vista of years, the highlights of achievement stand out clearly as unique and solitary beacons, lonely as ghosts. But it is easier to focus the invention of writing thousands of years ago as an event, an episode occupying a negligible time, than it is to get the contemporary scene into perspective. Yet we know well that writing and its diffusion occupied millennia, from the first drawings and pictographs to the finished alphabet; just as we know that the release of atomic energy in our own time was preceded by decades of research, which led gradually to the climax. (The diffusion of this knowledge over the entire world will hardly take as long.)

In order to determine whether the discovery of atomic energy is or is not comparable with the revolutionary footsteps herein described, let us ask ourselves a few questions, and abide by such answers as we can devise.

(i) Does atomic energy differ in quality from other kinds of energy, or only in the scope and intensity of its effects?

(ii) If atomic energy *does* differ fundamentally from energy derived from other sources, what exactly has been achieved? What is the crux of all this theory, experiment and research? Is it the release of power, or is it something quite different, of which the release of power is only one manifestation?

(iii) Again, if it is something different, something new, has the peak result, towards which all this long involved research has – presumably – been directed, yet been reached? Or are physicists – astro-, nuclear and whatnot – striving to reach some more final result, some Utopia, perhaps, of which we (and probably they themselves) have no inkling?

(iv) If it is possible to say categorically, that atomic energy is something quite different from other forms of energy, was the first step in unravelling the plot itself revolutionary, and deliberate, or just a lucky chance? What *was* the first clue to the atomic world? What invention or discovery put the research worker on the track?

(v) What exactly, in a word (or in a phrase), *has* been discovered or invented? And most crucial of all, will the whole human race, in the long run, benefit from atomic energy, as it has benefited from the invention of writing, the domestication of animals and plants, and the discovery of power? Or is it reversible?

On the answers to these questions (though some of them appear rather academic) must depend our assessment of today's discovery. If they fulfil our somewhat arbitrary conditions, we must admit that Man is, here and now, in the act of taking a step forward such as he has not taken for centuries, and perhaps not since prehistoric times.

Before answering them, however, let us first clear up the common and inevitable misunderstanding which equates atomic energy with the 'bomb' and with nothing else. Until the destruction of Hiroshima and Nagasaki, very few people had ever heard of atomic energy. Perhaps the commoner phrase was 'nuclear physics'. For until the energy of the atom *had* been released, atomic energy was but a dream. However, even in 1939, it was a dream which was near to coming true.

The 'bomb' is, of course, atomic energy in its lowest manifestation, and it is certain that, but for the war and the stark struggle for survival, atomic energy would never have been released in such a form, at any rate to begin with. By now everybody knows the atomic bomb to be by far the most potent weapon of mass sudden death in existence. And indeed, although the closely guarded secret of it is known to few people, and still fewer societies have both the knowledge and the resources to make an atomic bomb, it is nevertheless remarkable that people in the remotest part of the world, isolated in the bosom of the Pacific Ocean – people furthest from the main current of western thought and action, should have personal experience of atomic power within a few months of theory being translated into practice; though not, perhaps, more remarkable than that immediately the first bomb was dropped on Hiroshima the whole world should have heard of it. Yet never before in the history of Man has he been so impotent to make use of a major invention.

Today, then, all over the world, mankind is equating atomic energy with an earth-shaking explosion. Now, explosion as ordinarily understood is a combustion so rapid as to be practically instantaneous. It is a chemical reaction which depends on the decomposition and recombination of substances, such that a huge volume of hot gas is liberated at a high temperature. This liberation of hot expanding gases is, in fact, the essence of explosion. The atomic 'bomb' – and the word is unfortunate, if inevitable – does not cause an explosion at all in this sense, for no gas is liberated. It does, however, behave like an explosion. (So also might a cyclone be said to behave like an explosion!) The atomic bomb depends for its effect not on the *interactions* of matter, with formation of different matter and state of matter, but on the *annihilation* of matter. Thus it is not really a bomb at all, any more than a cyclone is a bomb; but it is now too late to call it by another name. Clearly, it is not just a development of some simpler thing, as T.N.T. may be said to be a development of dynamite. It is something entirely new, different in kind. It is the difference between changing one state of matter into another state (as a solid into a gas), and annihilating matter altogether. The annihilation of matter releases a huge store of energy, which was locked up in the creation of matter.

The inescapable connection between atomic energy and the atomic bomb is the more unfortunate because of its power, in ordinary speech, to annihilate the target against which it is directed. In a scientific sense it does nothing of the sort; it is not the target, but the bomb, which is annihilated.

Our footsteps, as I have already insisted, refer to material things which you can touch and see. They are concerned with inventing something, or with discovering some principle, in accordance with which something can be made, or some work done, or human labour saved – for life is action. Several times I have digressed in order to consider the materials out of which things could at any given time be made, or the underlying principle on which the future manufacture of things depended.

Matter, then, for a half million years has been the key to material progress. And now, in the twentieth century, scientists turn round and ask: what *is* this matter? What *is* the stuff of which our machines are made?

Well may they ask! Already they are able to annihilate it, to create it, and to change the unchanging, irreducible elements into one another – a violent process. Matter, then, is nothing; or rather, it is not – matter. It is energy. In explaining matter, they have explained it away; matter, say the wise men of the West, has no existence, only the appearance of existence. That is revolutionary; and it is disconcerting that the latest step, the twentieth-century step which Man is in the act of taking, should start by denying the reality of matter, when we have just been describing half a million years of progress in terms of how Man has handled matter! Only in annihilating it has he mishandled it.

We may perhaps have domesticated all the animals we are ever likely to domesticate, until the wolf shall lie down with the lamb. We have invented so many and various written languages that it seems unlikely that we need ever invent any more, unless it be for universal acceptance; and that still seems far off. Though we replace our gravity and wind machines with steam engines, and our steam engines with internal combustion engines, yet all these are variations on a theme. Once the principle of natural or mechanical power

– the conversion of one form of energy into another, its storage and conveyance – is recognized, variations and improvements of all kinds follow.

But the same principle is maintained throughout; animal power replaces human power, natural power (gravity or wind) replaces animal power, mechanical power replaces gravity. At each stage new types of machine are needed. But there is all the difference in the world between power derived from gravity, or from combustion, or electromagnetic power, and power derived from the annihilation of matter. Nor is the present position easy to explain to the layman, since with nuclear physics we are denied all recourse to mental pictures; you cannot make a mental picture of an abstraction.

The layman can without undue strain imagine a drop of water magnified to the size of the earth, whereat the particles (molecules) of which it is composed would be smaller – but not much smaller – than cricket balls, and hence easily visible. And since the particles of matter with which the physicist deals are unimaginably minute, it requires no further effort on his part to subdivide a molecule a thousand or ten thousand times, and to continue subdividing it until he arrives at a particle the size of an electron, which is part of an atom. Still without completely dislocating his intellect he can imagine these almost infinitesimal particles, each carrying an almost infinitesimal electric charge, whatever that may mean. Presumably it refers to a certain state. He cannot *picture* an electric charge, but he knows some of the properties of an electrically charged body, and how it would, under certain circumstances, behave.

But when he is finally told that subdivision has reached the limit, that this ultimate particle, the electron, is not to be pictured as a particle carrying an electric charge, but is the charge itself – that is to say, a state or condition of matter without the matter – his mind at last begins to reel. The charge, then, the particular state of matter, has become disembodied! Nor can the layman, by taking thought, add a cubit to his mental stature which will enable him to conceive so spectral a thing as a disembodied charge of electricity. It is no use; he must give it up. Matter has become the stuff of dreams, of nightmares; it has soared away into the *Ewigkeit* of nuclear physics and astrophysics. It has become so tenuous, that (if it is any consolation to him) even physicists themselves cannot tell each other in so many words what has happened to it; they can only converse in mathematical symbols. For that reason alone (since few of us understand mathematics at the highest level, in the realms of non-Euclidian geometry) it is quite useless to try to explain to the layman what has happened to matter. It has been abolished, no less.

It would, of course, be foolish to suggest that fifty years of research by the most brilliant thinkers of the day have resulted in no more than the discovery of the electron and the invention of the atomic bomb. It would be even more foolish to suppose that the outcome of this research can be briefly described – even in mathematical symbols. We are much too close to it to get it in sharp focus. Not till we can look back on the completed work from a long way off will it be possible to sum up the achievement for mankind in a phrase. Referring again to our analogy of the lamp-lit street, we ourselves stand in the market place under the glare of the arc lights, and are bemused.

How long has this research, which to date has culminated in the atomic bomb, been going on? We know that most of the footsteps we have described took many centuries at least to reach even temporary perfection. But atomic physics is considerably less than a century old. The actual experiment which led the most acute minds into the new highway was the electrical discharge in a vacuum, an experiment performed in the Cavendish Laboratory, Cambridge, in the last decade of the nineteenth century. But there had been preliminary skirmishes before that. Clerk Maxwell, also at Cambridge, and Hertz, who had detected radio waves, were in the van; and, of course, the heroic Curies, by discovering and isolating radium – an element in a state of spontaneous annihilation – played a big part in the drama. One might even go back to John Dalton (early nineteenth century) whose atomic theory did so much to prepare the ground. But the *immediate* cause was the discovery of the electron as a result of the experiment referred to, by J. J. Thompson, some fifty-five years ago.

That in the twentieth century we have been able to advance so far with a major discovery, which presently may revolutionize the world in which we live, is significant. It is not, however, surprising when we consider the number of research workers in physics, astrophysics, nuclear physics, chemistry, engineering, and I know not what, and how easily and quickly they can communicate their results to one another all over the world. Teams of scientists co-operate in the solution of a single minor problem. Experiments are conducted in almost any part of the globe, habited or uninhabited, in the polar regions, in the equatorial jungle, in the heart of the desert, on the sea and under it, and fifty miles above the earth's surface. In a very short time results are compared, integrated and conclusions reached.

Yet clearly we still await a complete synthesis of all these remarkable discoveries about matter, which has suddenly become the stuff of dreams. If the proof that matter is no more than an electric charge, disembodied, is highly theoretical, so also, at present, are the benefits to be derived from the discovery. For apart from possibly explaining many hitherto insoluble astronomical problems, such as the age of the universe and whence the stars (including our sun) derive their energy, the only practical application of all this knowledge so far appears to be the atomic bomb, the benefits of which are likely to be illusory.

Just as the gradual recognition of power – no *thing*, but a universal principle – led to the construction first of the simple machine, and later of the power machine, so too the discovery of disembodied matter may send mankind off, reinvigorated, on a new quest, away from much he would fain leave behind on the old. No man knoweth what the morrow holds, but for mankind there is always a morrow – and hope. A century hence Man may look back to the twentieth century, and viewing it in its true perspective, be able to say: 'To the pioneers we owe knowledge; to the twentieth century, wisdom.'

But it is in practical results that the layman (like mankind before him) is interested, especially material results. We, living in the atomic age, are immensely intrigued, because all the earlier steps were completed long before we were born. We want to know to what ends atomic energy will be put. The similes which have been used to describe how much power could be obtained by annihilating a pebble – power to drive a liner across the Atlantic and back – mean nothing to most of us. What interests *us*, seeking health and happiness, is how all this potential power will be used, how we shall benefit. We are not much concerned with the age of the universe, or with driving bigger ships faster across the Atlantic. We are not much concerned with more or better electric light, heat, or any other form of power laid on. Even less are we interested in more vigorous, rapid and complete methods of massively slaying our enemies, real or imaginary. And yet, so far atomic energy has been revealed to us only as a potential means of doing, more universally (but far more expensively), just those things which the more familiar kinds of power do adequately, if not perfectly. And so we get back to the atomic bomb, with its aura of fear.

It is hardly surprising, therefore, if the layman, not learned in nuclear physics, just buries his head in the sand and refuses to take any further interest. Everybody tells him that atomic energy is an inexhaustible source of irresistible power. On the other hand, experience tells him that what everybody says is nearly always wrong, if not foolish. We can then be fairly certain that any good which may come from the release of atomic energy will not primarily be due to it as a direct source of power, and we are left completely in the dark as to what it may be. We live, it seems, on the edge of a volcano which may at any moment prove to be active, though at present it is dormant. But there is also the possibility that it may prove to be extinct.

Yet it is perhaps more worth while to live in an age when, as we may well believe, mankind is actually engaged in taking a revolutionary plunge forward, rather than in an age which only marks time; in an age when we know the very names of some of the revolutionaries, even know a few of them by sight, or – most wonderful of all – to talk with.